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MECHANICAL EQUIPMENT

OF

FEDERAL BUILDINGS

UNDER THE CONTROL OF

THE TREASURY DEPARTMENT

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(SECOND REVISED EDITION)

NELSON S. THOMPSON

BALTIMORE
WILLIAMS AND WILKINS COMPANY
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In presenting to the public the basic data used in designing the Mechanical Equipment for buildings under the control of the Treasury Department, I desire to give credit to N. R. Stansel, M. S. Cooley, H. M. Price, D. F. Atkins, A. R. Horn, H. C. Russell, E. L. Wilson, E. C. Stanton, C. R. Bradbury, J. L. Vawter, Myers Hand and L. A. Warren for their valuable contributions.

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CONTENTS

Heating and ventilation 1
Plumbing, drainage and water supply 46
Gas piping 72
Conduit and wiring systems 76
Lighting 101
Elevators 114
Small power plants 141
Motors and controlling apparatus 166
Vacuum cleaning systems 175
Operating data 198
Appendix—
    Commercial Practice 201
    Heating by forced circulation of hot water from a central station 245
    General instructions 256
    Suggestions to superintendents 265

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sion of the general public, unlimited funds are not available for the erection and equipment of government buildings, and in the very large majority of cases it is necessary to reduce the cost of the mechanical equipment to the lowest point, eliminating everything not absolutely essential.

Under the present policy in regard to new buildings, all the rooms have at least 1,800 cubic feet of space for each and every occupant, and in most cases electricity is used for illumination; and the area of the exposed windows and doors is always at least one-fourth the area of the floor. The main assembly room (post-office workroom) is frequently flushed out by the opening of exterior doors to admit and dispatch mails.

In view of the foregoing it was decided to eliminate the ventilating apparatus in the smaller buildings which were not provided with court rooms. In practically all the smaller buildings the steel smokestack of the boiler is placed inside of a brick shaft, and into this shaft openings provided with top and bottom registers are made which serve to draw air from the post-office workroom, the large basement toilet-room, and the room in the basement in which the letter carriers remain when off duty.

The small private toilet-rooms are used infrequently, and as they are provided with generous exterior windows vent flues are seldom installed.

When a building contains a court room, gravity-indirect radiation is installed sufficient to change the air not less than twice an hour in court room, which is provided with a vent flue or flues, connected with the vent shaft.

The court room is heated by direct radiation, the indirect merely heating the air to 75°.

Where conditions preclude the installation of gravity-indirect stacks for the court room, direct-indirect radiators are installed to supply ventilation, and vent flues as above noted are installed also.

In the large buildings all the heating is done by direct radiation, and the fresh air is admitted to the rooms to be ventilated at about 75° F. The ventilation in the large buildings is confined mainly to the post-office workrooms and the court rooms (rooms in which a number of people assemble), and the principal office rooms.

The advantages of this system are that the ventilating apparatus may be shut down from, say, 6 p.m. to 8 a.m., and the direct radiation kept in service continuously in order to prevent the building cooling off. An accident to the fan motor does not cripple the entire heating and ventilating system as is the case with the straight hot-blast system.

In the larger buildings the post-office section is in operation night and day continuously, and it is imperative that sufficient heat be obtainable at all times.

In several of the large buildings constructed by the office in earlier days the vent flues from the office rooms were omitted, and the fresh air which was forced in by the fan found an outlet through crevices around windows and entrance doors. This is now overcome by installing metal weather-strips in all buildings provided with mechanical ventilation, and, wherever the construction permits, installing vent flues from the apartments supplied with fresh air.

Even with metal weather strips, when air is admitted for ventilation only, it is not deemed absolutely necessary to install vent flues in each office room. The vent flues or registers provided in the assembly rooms and main toilet-rooms are ample to carry off all the air forced in by the fan.

Vent registers installed in entrance doors from corridors are regarded as useless and unsightly.

In all buildings equipped with a plenum fan the practice is to install an air washer, as such a device is looked upon as the most essential feature of a successful ventilating apparatus. The old ventilating apparatuses were a failure on account of the inability of the dry air filter to cleanse the air properly. In a test recently made by a representative of the office of the Supervising Architect a new cheese-cloth filter reduced the delivery of the fan 25 per cent when air was passing through the filter at the rate of 2 feet per second.

No heating and ventilating apparatus is complete without some means of absolutely and automatically controlling the temperature of the apartments, and when funds are available a first-class automatic temperature-controlling apparatus is installed in the larger buildings. Aside from the comfort thus assured, a saving of not less than 10 per cent in the coal pile may be secured.

When it is certain that an automatic temperature-controlling apparatus is to be installed, the radiation is not split into small units as is the case when hand control only is to be used, and the reduction in the number of units offsets in a measure the cost of the automatic temperature-controlling apparatus.

The method adopted by the office for controlling the temperature of the tempering and reheating coils when air for ventilation only is to be supplied is as follows:

Provision is made for a by-pass damper or dampers under both the tempering and reheating coils. The dampers are made equal in area to not less than 10 per cent of the gross area of the coils and not larger than 15 per cent of said gross area. All dampers larger than 20 inches x 36 inches are made of the louvre type. The tempering coils are made deep enough to heat the air from the lowest local temperature on record to 67° F., and the reheating coils deep enough to heat the air from 50° to 80° F. This arrangement allows for a 20° temperature drop due to air passing through the air washer.

To control the tempered air a thermostat is installed in the cold-air chamber, and is set to open the first row of coils when outside air is 10° F. This is a refinement which may be omitted if desired and hand-control valves only used on this section.

Two thermostats are installed between the air washer and the secondary or reheating coils. One is set at 45° F. to shut off the inside row or rows of tempering coils when air reaches that temperature after passing through the air washer; the other is set at 47° F. and operates the by-pass damper under the tempering coils. These thermostats are placed beyond the air washer so that the air will not become too saturated in cold weather.

The secondary coils are generally two or three sections deep, and one two-point thermostat is set near the fan inlet to control the steam inlet valves on same. One point of this multiple thermostat is set at 71° F. and shuts off the first row when air reaches that temperature; the second point is set at 73° F. and controls the second row of coils, or the second and third rows. as the case may be. A thermostat is also placed near the fan inlet and set at 75° F., and when air reaches that temperature it opens the by-pass damper under the secondary heating coils.

All thermostats have a range of 15° on each side of the point set, and those on the steam valves are positive and have a quick movement to open or shut the valves. The by-pass damper thermostats are of the gradual-moving or intermediate type.

The control where a plenum chamber or school-house system is used is the same as noted above in so far as the tempering coils and the by-pass under same are concerned, but on the reheating coils no automatic control is used and the valves on coils are hand-control type, or diaphragm type controlled by hand by three-way cocks. The temperature of the hot air is read on a thermometer in the hot-air chamber, and the engineer controls the reheating coils by hand.

In the ordinary office rooms one thermostat is placed to control the direct radiation. In large court rooms and in post-office workrooms two or more thermostats are placed, according to the judgment of the engineer in charge of the drafting room.

When a hot-water heating system is equipped with an automatic temperature controlling apparatus, the diaphragm valve is placed on the return end of radiators.

Complaints may be expected during the first season an automatic temperature-controlling apparatus is in use in a building, as the occupants throw the thermostats out of adjustment, owing to unfamiliarity with the workings of the system. As soon as they have acquired sufficient experience to avoid this, the apparatus invariably gives satisfaction.

Attention is called to the fact that the automatic temperature-controlling apparatus must be of the very highest grade, or it will be worse than useless.

In connection with installing automatic temperature control on a low-pressure heating apparatus, the office will install an air-removal system with a water-operated vacuum pump on jobs containing 2,000 square feet and less, and for over 2,000 square feet, an electrically-operated air-compressor. The patents have expired on this system where no pressure-reducing valve is used; therefore no royalty is required.

This system is especially desirable when automatic temperature control is used, and is being placed in the large buildings where low-pressure steam is generated, even when not provided with automatic temperature control, to assist in air removal and insure quick heating.

In large buildings where an electric generating plant is to be installed an air-line system, or one of the standard vacuum systems with special valve on return end of each radiator is installed. This reduces the back-pressure on the engine and insures quick heating of a large amount of radiating surface. These devices, under the conditions noted above, are a satisfactory and economical adjunct to the mechanical equipment.

The office does not regard with favor the various atmospheric or vapor systems of steam heating on the market as applied to plants in small Federal buildings, for the reason that under the usual operating conditions few or none of the advantages claimed for these systems would be secured. As an experiment, the office has installed a number of vapor systems of different makes, and their operation in actual service will be checked against the claims made for them. The argument advanced for most of the vapor systems, i.e., that a certain amount of temperature control is thereby secured, is not given much weight by the office, as practical heating engineers are aware that hand manipulation of valves by individuals to secure temperature control is generally unsatisfactory.

In the smaller buildings the standard one-pipe gravity-return steam heating apparatus, such as installed by the office, gives first-class results, as it is simple in construction and operation, and will circulate at atmospheric pressure.

When automatic temperature control can not be used, the office endeavors to secure a certain amount of temperature control in connection with its steam heating systems by installing at least two radiators in all apartments with two or more windows, so that in mild weather one radiator may be shut off and remain out of service. This is, of course, a makeshift, but it is the best solution when funds are limited.

When money is available for the purpose, the practice of the office will be to use hot air as the heating medium for buildings located on the Pacific coast south of Los Angeles, and on the Florida peninsula; otherwise direct steam will be used.

In localities where the lowest recorded temperature is not below 10° F., and sudden changes are not common, direct hot water will be used; and in cities where there is a district heating company, using hot water as the heating medium, hot water will be used without reference to climatic conditions.

With the above exceptions, steam heating is used, and experience has demonstrated that under all conditions it is generally more satisfactory in operation than any other system in Federal buildings.

If a district heating system is in operation in a city in which a Federal building is to be erected or remodeled, the heating apparatus is so designed that it may be operated from the district heating system or from boilers installed in the building. The boilers are always installed, to serve as a check on the cost of outside service and for use in case of a break-down in the district system; but usually it is equally economical and more satisfactory to purchase steam or water for heating rather than to generate it in the boilers provided.

The practice of the office is to ascertain the amount of radiation required by the B.t.u. method, and the results are checked by the experience and judgment of the chief mechanical and electrial engineer.

BASIS FOR CALCULATING RADIATING SURFACE

Lowest temperature on record in the locality is ascertained from the Weather Bureau reports. If the city has no station the results are taken from the nearest station thereto.

In southern cities, where the lowest recorded temperature occurs infrequently, and then only for a day or two, the calculation is based on a temperature 10° in excess of the lowest on record for the previous ten years.

In northern cities where the temperature goes below 10° and remains around zero for several days, the calculation is based on lowest temperature recorded during the previous ten years.

All office rooms, the post-office workroom, court rooms, corridors, lobbies, letter carriers' swing room, and all toilet-rooms containing bathing facilities are heated to 70° F. General toilet-rooms which do not contain bathing facilities are never heated above 60° F. In southern latitudes where the calculation is based on 20° F. or above heat is not provided for any toilet room except that for the carriers. Small toilet-rooms which open from office rooms are not provided with heat where lowest recorded temperature is not below zero.

After determining the temperature upon which the calculation is to be based, the heat losses are ascertained by the B.t.u. method, using the following coefficients for glass and wall, etc., based on Prof. Homer Woodbridge's calculations of heat transmission per degree difference in temperature between inside and outside air:

Solid brick wall

Inches	One wall exposed	Two walls exposed
12	0.265	0.232
18	0.210	0.205
21	0.187	0.185
24	0.167	0.150
27	0.152	0.140
30	0.140	0.130
33	0.130	0.120
36	0.120	0.113
40	0.112	0.103

Hollow brick wall

Inches	One wall exposed	Two walls exposed
12	0.220	0.170
18	0.175	0.137
21	0.160	0.125
24	0.147	0.115
27	0.135	0 105
30	0.125	0.097
33	0.117	0.090
36	0.110	0.084
40	0.100	0.077

Solid granite or marble wall

Inches	One wall exposed	Two walls exposed
12	0.400	0.335
18	0.340	0.290
21	0.315	0.275
24	0.295	0.260
27	0.280	0.245
30	0.265	0.232
33	0.250	0.220
36	0.235	0.210
40	0.220	0.200

Hollow granite or marble wall

Inches	One wall exposed	Two walls exposed
12	0.305	0.245
18	0.270	0.215
21	0.255	0.202
24	0.240	0.190
27	0.228	0.180
30	0.218	0.172
33	0.208	0.164
36	0.200	0.157
40	0.190	0.149

Brick walls with sandstone faces, plastered on inside

Brickwork	Thickness of sandstone face		
Inches	4 inches	8 inches	12 inches
4	0.31	0.29	0.26
8	0.22	0.20	0.19
12	0.17	0.16	0 15

Inches	Concrete or sandstone	Limestone
12	0.45	0.49
16	0.39	0.43
20	0.35	0.38
24	0.31	0.35
28	0.28	0.31
32	0.26	0.28
36	0.24	0.26
40	0.22	0.24

Above constants are for walls furred and plastered on the inside with 2-inch terra cotta or wood furring. For walls not furred or plastered add 20 per cent.

Outside walls of frame buildings, lath and plaster inside, outside construction as below:

Ordinary overlapping clapboards $\frac{7}{16}$-inch thick	0.44
Same with paper lining	0.31
Same with $\frac{3}{4}$-inch sheathing	0.28
Same with $\frac{3}{4}$-inch sheathing and paper	0.23

Inside partitions consisting of 4-inch studs with lath and plaster on one side and the other side as below:

Nothing	0.60
Lath and plaster	0.34

For various roof surfaces, as follows:

Slate on wood for framing only	0.80
Slate on tight wood sheathing	0.30
Iron on wood for framing only	1.32
Iron on tight wood sheathing	0.17
Patent roof (tar and gravel, paper, etc.)	0.30
Tiling $\frac{3}{8}$-inch to 1-inch thick	0.80
Six-inch hollow tile—2-inch concrete and tar and gravel covering	0.36
Eight-inch hollow tile—2-inch concrete and tar and gravel covering	0.40
Four-inch concrete with cinder fill	0.60
Six-inch concrete with cinder fill	0.54

For various floor surfaces, as follows, assuming temperature of earth as 50° F:

Cement or tile (no wood above)	0.31
Cement or tile (wood floors above)	0.08
Dirt (no floor whatever)	0.23
Ordinary, single, wood near ground	0.10
Wood, single, no plaster beneath joists	0.10
Wood, double, no plaster beneath joists	0.08
Wood, single, with plaster beneath joists	0.08
Wood, double, with plaster beneath joists	0.06

For various ceilings as follows, assuming temperature of attics as 30° above lowest outside temperature:

Cement or tile (no wood above)	0.39
Cement or tile (wood floor above)	0.10
Lath and plaster (no floor above)	0.32
Lath and plaster (single floor above)	0.26
Fireproof ceiling (metal lath, no wood above)	0.49
Fireproof ceiling (metal lath, wood floor above)	0.15

For various glass surfaces as follows, assuming exterior doors same as glass, and measuring the openings in brickwork for glass surface:

Glass in single windows	1.00
Glass in double windows	0.50
Glass in single skylight	1.50
Glass in double skylight	0.50
Glass in single monitor	1.35

In rooms over 12 feet high the heat loss is increased by an amount due to the rise in the mean internal temperature, and by the increased rate of air movement over the interior surface of the wall. This increase is practically 2 per cent for each foot of ceiling height over 12 feet.

The preceding tables are for southern exposure. Maximum allowance for other exposures should be made as follows:

	Per cent
North, add	35
West, add	25
East, add	15

To this add the following for loss due to leakage:

	Per cent
For office rooms	35
For main lobby, post-office workroom, and court room	65

Allow for direct steam radiation, standard 3-column 38-inch high radiator, 270 B.t.u., and for water 180 B.t.u., per square foot per hour. When a vapor system is used 250 B.t.u. are allowed per square foot of direct radiation.

If a direct radiator is inclosed in a window breast with a proper arrangement for circulating air over it, allow 200 B.t.u. for steam and 120 B.t.u. for water. Three square inches net area in registers or grills to concealed radiators are allowed per square foot of radiating surface.

If a direct radiator is to be placed under a window seat, 220 B.t.u. are allowed for steam, and 140 B.t.u. for hot water radiation.

The foregoing rules are not applicable when a building is provided with metal weather strips. In such cases the following formula is used:

G = area of glass in square feet.
W = area of wall in square feet, less glass.
10 = A constant for all brick walls up to 24 inches thick.
30 = a constant for ceilings.
T = temperature of room (70°).
T_1 = temperature of steam (210°).
t = lowest outside temperature.

The square feet of direct radiation required for all average-size office rooms $= \left(G + \frac{W}{10} + \frac{C}{30}\right)\frac{T-t}{T_1-T}$.

For first-floor lobbies, post-office workrooms, court rooms, and large office rooms add 25 per cent to the result obtained above.

If there is a skylight in the room, divide the area of sky-light by 5 if steam is the heating medium and add the result to the above formula.

No allowance is made for exposure to north, west, or east.

As a rule the above will check closely with the result obtained by ascertaining the radiation required by the B.t.u. method previously given and then deducting 10 per cent for use of metal weather strips.

The rule used for Federal buildings by the representative of one of the most prominent metal weather-strip manufacturers is as follows:

G = area of class in square feet.
W = area of wall in square feet, less glass.
C = ceiling in square feet.
$\frac{7}{10}$ = a constant.
4 = a constant.
12 = a constant.
0.44 = a constant for steam.
0.6 = a constant for hot water.

Direct radiation = $\left(\frac{7G}{10} + \frac{W}{4} + \frac{C}{12}\right) \times 0.44$ for steam and 0.6 for hot water.

This rule is used by the company where the lowest temperature on record is $-10°$ to $0°$. No allowance is made for exposure.

Direct-indirect radiation. For direct-indirect heating, a speed of 5 feet per second through the cold-air inlet duct to the radiator is assumed, to ascertain the amount of air which must be raised from exterior temperature to that of the room. This speed has been observed in several anemometer tests of these systems.

The heat losses through wall and glass are ascertained by using the exposure factor the same as in direct radiation, but in lieu of using leakage factors the number of B.t.u. required to raise the temperature of air introduced through radiator from lowest recorded exterior temperature to room temperature is ascertained. Three hundred B.t.u. per square foot for steam radiators and 200 for hot water are allowed. In selecting the boiler the direct-indirect is reduced to direct equivalent by adding 20 per cent to the actual direct-indirect radiation installed.

Vent flues with a positive outflow, such as is created by a fan or an aspirating coil, must be provided to assist the inflow of air through the direct-indirect radiators. A speed of 3 feet per second in vent flues connected to a properly located roof ventilator without aspirating coil is allowed.

This system is sometimes employed with hot-water heating apparatus, but where the lowest temperature on record is below 5° F. its use is not desirable on account of the danger of freezing the radiators.

Gravity indirect radiation. Assume that the temperature of entering air under extreme outside conditions will be 120° F. for steam and 100° F. for hot water.

The amount of radiation to install is ascertained by the B.t.u. method, taking into account the heat losses through wall, glass, and ceiling, and making allowance for exposure; and in addition allowing 10 per cent for loss of hot air through window cracks if metal weather strips are not used. The B.t.u. ascertained as above, multiplied by 55, and divided by 50 for steam and 30 for hot water, will give the number of cubic feet of air which must be admitted to the apartment per hour to heat it.

The number of B.t.u. required to raised the temperature of the air from the lowest outside temperature to 120° F. for steam and 100° F. for water, plus 5° allowance for temperature drop in flue, is ascertained and the resulting number of B.t.u. divided by 350 for steam indirect, natural draft, and by 220 for hot water indirect, natural draft.

The size of hot-air flues and ducts to be installed is ascertained by assuming the following speeds:

Air speed to first floor, 200 feet per minute.
Air speed to second floor, 300 feet per minute.
Air speed to third floor, 400 feet per minute.

The vent flues (which are always installed with this system) and cold-air ducts are made the same size as hot-air flues.

In climates where the lowest temperature is −10° F. and below, 12-inch or 15-inch deep extended-pin radiators are used for steam, and in all climates similar radiators are used for water. For climates where temperature is below −10° F. two 12-inch deep radiators are used for hot water.

The allowable speed through cast-iron pin-indirect radiators for natural draft is limited to approximately 2 feet per second through one section deep. High speeds necessitate the placing of one section on top of another with a space of about 4 inches between the sections. Five feet per second through the radiator is the limit with natural draft.

The check rule for indirect flues when room is to be heated by hot air is to make same equal in square inches to the area of glass in square feet plus one-fourth the area of exposed wall in square feet; no flue to be wider than three times its depth. The check rule to determine amount of indirect radiation is to divide the cubic feet of air to be delivered per hour by 200 when air must heat and ventilate the room, and by 300 when air is for ventilation only.

None of the cast-iron extended-pin indirect radiators (except the "Vento") contain the amount of surface given in the manufacturers' catalogues, and, to be conservative, 20 per cent of the amount claimed should be deducted in making the layout.

DIMENSIONS OF PIPING

ONE-PIPE STEAM MAINS FOR RUNS UP TO 200 FEET IN LENGTH

Size of flow pipe	Radiation	Dry return	Wet return
Inches		*Inches*	*Inches*
1	40	¾	¾
1¼	75	1	¾
1½	126	1	1
2	286	1¼	1
2½	535	1½	1
3	890	1½	1
3½	1,360	2	1
4	1,950	2	1
5	3,600	2½	1¼
6	5,900	3	1½
8	12,700	4	2
10	22,900	5	2½
12	37,000	6	3

The foregoing sizes of returns are safe and are used where funds are limited; but under ordinary conditions in circuit jobs the returns are made one-half diameter of steam main plus one pipe size, i.e., a 4-inch steam main would have a 2½-inch return pipe; either wet or dry.

For other lengths of runs see formula given with the 2-pipe schedule. In patent steel steam boilers two tappings are used of such size as to keep velocity of steam in the verticals down to not over 20 feet per second.

ONE-PIPE DIRECT RADIATOR TAPPINGS, ARMS AND RISERS

Square feet	Tapping	Riser and arm in basement and radiator arm
	Inches	*Inches*
0–20	1	1
21–24	1	1¼
25–40	1¼	1¼
41–60	1¼	1½
61–80	1½	1½
81–100	1½	2
101–200	2	2

TWO-PIPE HOT-WATER BASEMENT MAINS, GRAVITY CIRCULATION, DIRECT RADIATOR TAPPINGS

First floor	Second floor	Third floor	Fourth floor	Pipe size
				Inches
40	50	60	70	¾
70	80	90	100	1
110	120	135	150	1¼
180	195	210	230	1½
300	350	400	500	2

At ends of mains increase tapping one size. No main to be less than 1¼ inches.

To get size of mains and risers serving more than one radiator, add area of tappings together and use the following:

Equalizing table

Inches			Inches		
½	equals	2	3	equals	175
¾	equals	5	3½	equals	260
1	equals	10	4	equals	380
1¼	equals	20	5	equals	650
1½	equals	30	6	equals	1,050
2	equals	60	7	equals	1,600
2½	equals	110	8	equals	2,250

To get size pipe to serve a ¾-inch pipe and a 1-inch pipe:

¾ inch equals 5
1 inch equals 10
—
15 equals 1¼ inch

Two-pipe gravity down feed hot-water piping. Flow main in attic and return in basement.

Radiator tappings, same on all floors:

Square feet	Flow Inches	Return Inches
0– 50	¾	¾
51–100	1	1
101–200	1¼	1¼

The sizes of mains and risers serving more than one radiator are ascertained by adding the areas of tappings and using the preceding equalizing table. In this connection the main riser pipe from boiler to attic may be greatly reduced in size if a proper chamber, or the expansion tank, is placed at the top of the main riser.

The size of main riser may be taken from the following table:

Inches	Square feet direct radiation
1½	300
2	600
2½	1,200
3	2,000
3½	2,500
4	3,500
5	6,000
6	10,000

One-pipe circuit hot water. Use the same tappings and risers as given for 2-pipe hot water.

To arrive at size of one-pipe circuit hot-water mains, the following sizes are used:

Pipe sizes	200-foot runs	300-foot runs
2	200	180
2½	400	300
3	600	500
3½	900	700
4	1,200	1,000
5	2,300	1,800
6	3,600	3,000
7	5,200	4,000
8	6,800	6,000

A 1-inch or 1¼-inch starting pipe is used with this system.

The length of mains is measured back to boiler.

Tees on main are kept 2 feet apart. Risers are taken out of main on 45° and first floor connections out of top of main. All returns are taken into side of main. No special fittings are used except twin ells on mains where they branch.

Radiators assumed to transmit 250 heat units per square foot per hour. The following table is for pipes 200 feet in length. For pipes of greater length, multiply results in table by $\frac{200}{e}$, in which "e" equals length in feet. The values of this expression for different lengths of pipe are: For 300 feet multiply by 0.66⅔; for 400 feet, by 0.50; for 500 feet, by 0.40; for 600 feet, by 0.33; for 800 feet, by 0.25; for 1,000 feet, by 0.20.

TABLE FOR MAINS, RISERS, AND TAPPINGS FOR TWO-PIPE STEAM HEATING SYSTEM, TWO POUNDS AND FIVE POUNDS STEAM PRESSURE

Diameter of supply in inches	Diameter of return in inches	Two pounds pressure, total heat transmitted, B.t.u. per hour	Radiating surface in square feet	Five pounds pressure, total heat transmitted, B.t.u. per hour	Radiating surface in square feet
¾	¾	5,000	20	10,000	40
1	¾	9,000	36	15,000	60
1¼	1	18,000	72	30,000	120
1½	1¼	30,000	120	50,000	200
2	1½	70,000	280	120,000	480
2½	2	132,000	529	220,000	880
3	2½	225,000	900	375,000	1,500
3½	2½	330,000	1,320	550,000	2,200
4	3	480,000	1,920	800,000	3,200
4½	3	690,000	2,760	1,150,000	4,600
5	3½	930,000	3,720	1,550,000	6,200
6	3½	1,500,000	6,000	2,500,000	10,000
7	4	2,250,000	9,000	3,750,000	15,000
8	4	3,200,000	12,800	5,400,000	21,600
9	4½	4,450,000	17,800	7,500,000	30,000
10	5	5,800,000	23,200	9,750,000	39,000
12	6	9,250,000	31,000	15,500,000	62,000
14	7	13,500,000	54,000	23,000,000	92,000
16	8	19,000,000	76,000	32,500,000	130,000

Cast-iron boilers. As the experience of the office has demonstrated that cast-iron sectional boilers are usually unsatisfactory in maintaining a steady water line and frequently crack and break under service conditions, they are used only where structural reasons forbid the installation of steel boilers, and in such cases the proper size is ascertained by adding to the actual direct radiation installed 25 per cent for mains if anthracite coal is used, and 35 per cent if soft coal is used; and installing two boilers, each rated to carry two-thirds of the required service. Either boiler will then, if forced, carry the radiation for a few days in case of a breakdown in the other boiler.

To obtain the size of the stack when cast-iron sectional boilers are used, the formula is:

$$\text{Area in square feet} = \frac{\text{area of grate in square feet} \times 0.75}{\sqrt{\text{height of stack in feet}}}.$$

The tappings for steam connections are made not less than two in number, and their area must be such that the velocity of steam will not be over 12 feet per second in the verticals.

Returns are connected into both sides of each cast-iron boiler.

A 2-inch equalizing pipe from the *bottom* of the main header into the main return header is always installed on patent steel or cast iron boilers.

Steel boilers. In small Federal buildings in which a down-draft furnace is not to be used, consideration is given to the installation of a round vertical steel boiler. Except in certain special cases, the maximum size used of this type of boiler has a 28-inch diameter grate.

In order to comply with local smoke ordinances, now existing in nearly every city of any size, down-draft furnaces are installed where soft coal must be used, *except* where the size of horizontal boiler required is such as to serve less than 2,600 square feet of direct steam radiation. In such cases the Federal building is approximately the same size as a large residence, and, like a residence, local smoke ordinances are not applicable thereto.

The down-draft type of furnace is peculiarly suited to low-pressure heating boilers, as it has no moving parts, and a low grade of labor can be taught to fire it properly.

STANDARD BOILER TAPPINGS, STEAM AND WATER, FOR STEEL BOILERS OF THE "IDEAL" AND "CENTURY" TYPE

Steam

Rating	Flow	Return	Safety valve
	Inches	*Inches*	*Inches*
1,200	2-4	1-2½	2
1,500	2-4	1-2½	2
1,800	2-5	1-3	2½
2,200	2-5	1-3	2½
2,600	2-5	1-3	2½
3,000	2-6	1-4	2½
3,600	2-6	1-4	3
4,500	2-6	1-4	3

Water

Rating	Flow and return, each	Safety valve
	Inches	*Inches*
2,000	2-4	2
2,500	2-4	2
3,000	2-5	2½
3,600	2-5	2½
4,300	2-5	2½
5,000	2-6	2½
6,000	2-6	3
7,500	2-6	3

Where small size anthracite coal is the cheapest fuel, the maximum openings in the grate bars are specified not to exceed $\frac{3}{16}$ inch. The size of boiler when small anthracite coal is to be used is obtained by adding 40 per cent to the actual direct radiation installed.

When the cost of 20,000 cubic feet of natural gas is cheaper than one ton of coal, the boiler is equipped with burners, pilot light, and governor. The rating of boiler for use with gas is ascertained by adding 25 per cent to the actual direct radiation installed.

When bituminous coal is the cheapest fuel, the boiler rating is obtained by adding 35 per cent to the actual amount of direct radiation installed.

When three times the cost of oil per barrel plus the cost of seven kilowatt-hours of electric current per day (generally 70 cents) is less than the cost of one ton of coal, oil is used and the boiler is equipped with oil burners, pump, tanks, etc. The office is reluctant to install oil burning apparatus, as it involves the use of motor and pump, which the class of labor employed in the small Federal buidings is not, as a rule, competent to handle. Unless the annual saving of oil over coal will amount to at least $200 per year, coal is used.

The size of boiler for use with oil is ascertained by adding 25 per cent to the actual direct radiation installed.

When the size of the patent steel boiler required exceeds 3,000 square feet, consideration is given to the advisability of installing (1) two small, horizontal, portable, steel boilers, (2) a 3,600-foot horizontal, portable, steel boiler, or (3) a horizontal return-tubular brick-set boiler.

All the ratings given above are direct steam ratings, but the remarks apply to hot water boilers of equivalent capacities.

If a horizontal, return-tubular, brick-set boiler is to be installed, it is proportioned as follows:

R = total direct radiation in building, in square feet.
$B.H.S.$ = heating surface in boiler, in square feet.
G = area of grate in square feet.

$$B.H.S. = \frac{R}{7} \text{ for steam; } = \frac{R}{11} \text{ for water.}$$

$$G = \frac{B.H.S.}{25} \text{ for anthracite, pea, or rice coal.}$$

$$G = \frac{B.H.S.}{30} \text{ to } \frac{B.H.S.}{35} \text{ for bituminous coal, plain grate.}$$

$$G = \frac{B.H.S.}{45} \text{ for lower grate of down-draft furnace.}$$

H = height of stack in feet.
A = area of grate in square feet
S = area of stack in square feet.

$$S = \frac{A}{\sqrt{H}} \text{ for anthracite coal, lump coal, oil, and gas.}$$

$$S = \frac{A}{\sqrt{H}} \times 1.25 \text{ for bituminous and small anthracite.}$$

For anthracite, pea, or rice coal, the tube area must be not less than one-eighth grate area and be always larger than stack area.

For boilers with down-draft furnace attached, the tube area must be not less than one-sixth area of lower grate, and be always larger than stack area.

Maximum length of tube must not exceed 48 diameters.

Maximum length of boilers 54-inch diameter and under must not exceed 3 diameters; over 54-inch $2\frac{1}{2}$ diameters.

Tubes an odd number of feet long are not used.

Coal consumption for low-pressure heating apparatuses in tons per heating season may be found for Government buildings by multiplying by 5 the area of grate or grates in square feet, which will give the number of tons of coal burned per heating season of 240 days.

A safe rule is that for each cubic foot of contents of building one pound of coal will be required for heating season of 240 days.

The district steam heating companies usually estimate that each square foot of direct steam radiation will require 500 pounds of steam per season.

To find size of coal storage room for a government building, ascertain maximum consumption of coal for entire heating season and allow 8 square feet of floor space per ton.

To ascertain boiler horse-power for direct heating of a building in New York City or a similar climate, allow 100 boiler horse-power for each 1,000,000 cubic feet of contents for zero weather, and in average winter weather two-thirds of this will be the horse-power required. Between 40 and 50 per cent of the maximum will be the boiler horse-power required for the full heating season of 5,700 hours.

The boiler horse-power in Federal buildings with a heating and ventilating apparatus will average one boiler horse-power for each 7,000 cubic feet of contents.

FAN SYSTEMS

As a general rule the fan is used to supply air for ventilation alone, and the trunk main system of distribution of air is used, but in exceptional cases where the fan is used for heating as well as for ventilating the plenum chamber system is used for the distribution of the hot air.

In other cases where requirements as to ventilation are not so exacting, but where it is desired to use fans for heating, sometimes on account of the construction of the building and again for reasons of control in climates of rapidly varying temperatures, the trunk main system is used; and if funds are available the air supply to the various rooms is automatically controlled by thermostats located in said rooms.

Amount of air to be circulated. When air is used for ventilation alone, and the number of occupants of any given room is not known, three to five changes of air per hour are allowed in post-office workrooms, court rooms, and carriers' swing rooms (depending upon the size, location, and opportunities for natural ventilation), and four air changes per hour in office rooms. When the number of occupants is known, 2,000 cubic feet of air per hour is allowed for each occupant.

When air is used for heating as well as for ventilation, the B.t.u. lost from the building are estimated exactly as heretofore given. The amount of air given above for ventilation is taken as the amount of air to be put into the room, and the temperature at which the air must enter the room to heat it is estimated. If this temperature is above 125° F. more air is to be circulated, 125° F. being taken as the maximum temperature of air entering a room, except in special cases.

Kind and size of fans. The regular style of steel plate or multiblade fans is used exclusively for plenum work. Disc fans are used only for ventilation without a heater, and then the total length of inlet and outlet pipe must be equivalent to not more than 100 feet of straight pipe of the diameter of the fan; and they are never required to work against any strong natural aspirating tendencies.

In such cases the motor is usually provided with a reversing switch, or rocker arm, so that the fan may be easily reversed and made to supply fresh air or to exhaust air, as desired. Curved blade fans are generally specified, and required to be of a type that when running "backwards" will handle not less than 75 per cent of the amount of air they will handle when running "forward."

Cone fans are used very seldom, and only where it is desired to reduce the power to a minimum at the expense of large ducts and much floor space.

On exhaust ventilation, where owing to length of ducts or other reasons a disc fan is not wanted, the steel plate or multiblade fan is generally used, although a cone fan, if it can discharge freely, is admirably adapted for this work.

Capacity and power. The capacity of any fan may be expressed by the formula:

$$C.F.M. = AD^3N, \text{ in which}$$

$C.F.M.$ = cubic feet of air per minute.
D = diameter of wheel in feet.
N = number of revolutions per minute.
A = a constant depending upon the kind of fan and the conditions under which it operates.

The horse-power may be expressed by the formula:

$$B.H.P. = \frac{D^5 N^3 S}{C},$$

in which D and N are as given above and

$B.H.P.$ = horse-power applied to fan shaft;

C = a constant depending on the kind of fan and the conditions under which it operates;

S = a constant depending on the temperature of air handled by fan, which is

$$S = \sqrt{\frac{460}{460+t}}$$

The values for A and C will be given for each of the following conditions for the various fans:

Case I. For a fan used for plenum ventilation only, and without an air washer.

Case II. Same as Case I, except that an air washer is used.

Case III. For a fan used for both heating and ventilation, and without an air washer.

Case IV. Same as Case III, except that an air washer is used.

Case V. For a fan used for exhaust or forced ventilation, when no resistance is encountered but the duct system.

Case VI. For a fan on free suction and discharge.

Steel plate fans. Proportions are assumed to be as follows:

Width periphery = 40 per cent diameter of wheel.

Width housing = 57 per cent diameter of wheel.

Diameter inlet in case = $62\frac{1}{2}$ per cent diameter of wheel.

Eight blades, set radially, not curved.

Multiblade fans.

Width periphery = one-half diameter of wheel.

Width casing = two-thirds diameter of wheel.

Diameter inlet in case = diameter of wheel (practically).

Wheels above 9-inch diameter have 64 blades, curved slightly forward in the direction of rotation.

Cone fans.

Width periphery = 25 per cent diameter of wheel.

Diameter inlet = 75 per cent diameter of wheel.

In the following table are given the values of A and C to be substituted in the general formulae given above for capacity and power of fans:

Case number	Kind of fan	A	C	Ratio of velocities
I	Steel plate	0.50	12,000,000,000	4
II	Steel plate	0.42	12,500,000,000	5
III	Steel plate	0.44	12,500,000,000	4
IV	Steel plate	0.40	13,000,000,000	5
V	Steel plate	0.56	11,500,000,000	
VI	Steel plate	0.62	11,000,000,000	
I	Multiblade	1.45	1,700,000,000	3
II	Multiblade	1.34	1,800,000,000	4
III	Multiblade	1.38	1,750,000,000	3
IV	Multiblade	1.10	2,250,000,000	4
V	Multiblade	1.70	1,500,000,000	
VI	Multiblade	1.95	1,250,000,000	
I	Cone type	0.55	13,000,000,000	5
II	Cone type	0.48	14,000,000,000	6
III	Cone type	0.48	14,000,000,000	5
IV	Cone type	0.45	12,000,000,000	6
V	Cone type	0.60	11,500,000,000	
VI	Cone type	0.73	11,000,000,000	
V	Propeller type	0.50	33,000,000,000	
VI	Propeller type	0.70	37,000,000,000	
VI	Disc	0.70	42,500,000,000	

The group "Propeller type" may be taken to cover the Davidson, American Sirocco, or Sturtevant propeller fans. The group "Disc" includes all straight-blade disc fans having twelve or more wide blades. It does not, of course, cover the ordinary desk fan.

The column headed "Ratio of velocities" in the table refers to the peripheral velocity of fan wheel divided by the mean velocity of air in the heating coils. The ratios given are maintained as nearly as practicable.

Speed of fans. Steel plate fans are run at a peripheral speed of 3,000 to 4,000 feet per minute, except when an air washer is used, when the speed must be about 4,500 feet per minute.

Multiblade fans are run at a peripheral speed of 2,500 to 3,000 feet per minute, and about 3,500 feet when an air washer is used.

Cone fans are run at a peripheral speed of 4,000 to 5,500 feet per minute, and at least 6,500 feet when an air washer is used.

Propeller type fans to operate at a peripheral speed of 2,500 to 6,500 per minute and disc fans from 3,000 to 8,000 feet per minute.

The formulae for power are based on 8-blade wheels about 6 feet diameter; sirocco wheels 4 feet diameter; cone wheels 6 feet diameter; and disc and propeller wheels 4 feet diameter. The horse-power should be increased about 5 per cent for each foot in diameter less than these diameters, to cover decrease in efficiency. No decrease in power for larger wheels.

Heaters. Heaters used with fans are usually of the cast-iron base type with wrought-iron pipe surface, or the all cast-iron heaters, such as the "Vento."

T = absolute temperature of the steam.
t_o = absolute temperature of the incoming air.
t = absolute temperature of the leaving air.
V = velocity of air leaving coil in feet per second.
A, B, and C, = constants to be used in formulae.

After having determined upon the peripheral speed of the fan, a heater is chosen to give the desired results with a velocity bearing as nearly as possible the ratio given in the table for the case in question.

Wrought-iron pipe coils.

$$t - t_o = \frac{ABt_o(T - t_o)}{C\sqrt{V} - A(T - t_o)}.$$

B.t.u. per square foot per hour = $A\sqrt{V}\ (T - t_o)$.

A = 2.55 for a coil 4 pipes deep.
A = 2.38 for a coil 8 pipes deep.
A = 2.25 for a coil 12 pipes deep.
A = 2.12 for a coil 16 pipes deep.
A = 1.95 for a coil 20 pipes deep.
A = 1.80 for a coil 24 pipes deep.
A = 1.68 for a coil 28 pipes deep.
A = 1.60 for a coil 32 pipes deep.
C = 12,850 divided by number of pipes in depth of heater.
B = 1.00 for pipes on $2\frac{3}{4}$-inch centers.
B = 1.07 for pipes on $2\frac{1}{2}$-inch centers.
B = 1.17 for pipes on $2\frac{1}{4}$-inch centers.

$$V = \left[\frac{A(T - t_o)\ (Bt_o + t - t_o)}{C(t - t_o)}\right]^2.$$

Friction. The friction in pipe coils on $2\frac{3}{4}$-inch centers is as follows:

Air velocity feet per minute	4 Rows	8 Rows	12 Rows	16 Rows	20 Rows	24 Rows
600	0.04	0.06	0.09	0.12	0.14	0.15
800	0.06	0.10	0.15	0.19	0.23	0.26
1,000	0.09	0.15	0.21	0.30	0.37	0.41
1,200	0.12	0.21	0.31	0.43	0.50	0.58
1,400	0.17	0.30	0.45	0.60	0.75	0.90

Friction is inches of water, and for any other velocities may be taken as varying as the square of the velocity.

The free air space with pipes on $2\frac{3}{4}$-inch centers = total number lineal feet of pipe in the heater, divided by the number of pipes deep, divided by 8.4.

All the above is for 1-inch diameter pipes. One and a quarter inch pipes at same air velocity will give practically the same B.t.u. per square foot per hour.

Sections should be tapped as follows:

Pounds steam per hour per section	Steam tap	Drip tap	Bleeder tap
	Inches	Inches	Inches
80	2	$1\frac{1}{4}$	$\frac{3}{4}$
160	$2\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$
320	3	2	$1\frac{1}{4}$
480	$3\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{2}$
960	4	$2\frac{1}{2}$	$1\frac{1}{2}$

Vento heaters.

$$\text{B.t.u. per square foot per hour} = A\sqrt[n]{V}\,(T - t_o)B$$

$$t - t_o = \frac{ABt_o(T - t_o)}{C\sqrt[n]{V^{n-1}} - A(T - t_o)}.$$

$$V = \left[\frac{A(T - t_o)(Bt_o + t - t_o)}{C(t - t_o)}\right]^{\frac{n}{n-1}}.$$

V, T, t, and t_o are same as given before, but A, B, C, and n are constants as follows:

For regular section on 5 -inch centers, $B = 1.00$
For regular section on $4\frac{5}{8}$-inch centers, $B = 1.09$
For regular section on $5\frac{3}{8}$-inch centers, $B = 0.87$
For narrow section on 5 -inch centers, $B = 0.77$
For narrow section on $4\frac{5}{8}$-inch centers, $B = 0.84$
For narrow section on $5\frac{3}{8}$-inch centers, $B = 0.67$

Number of sections deep	A	n	C
1	1.75	1.71	1,980
2	1.43	1.63	990
3	1.19	1.56	660
4	0.96	1.50	495
5	0.77	1.41	396
6	0.67	1.37	330
7	0.60	1.35	286
8	0.54	1.34	248

(In this table it makes no difference whether the sections are "regular" or "narrow" pattern.)

The free area in square feet = the total number of square feet of heating surface divided by the number of sections and this quotient divided by 17.6 for standard sections and by 12.1 for the narrow type sections. Long spacing ($5\frac{3}{8}$-inch centers) increases the free area 18 per cent over the standard spacing, and short spacing ($4\frac{5}{8}$-inch centers) decreases it to 85 per cent of the standard.

The following table gives the friction in inches of water for various depths of coils and various velocities.

Sections are on standard spacing (5-inch centers).

Velocity is volume of air measured at 70° F.

Velocity feet per minute	Regular section		Narrow section	
	One section	Add for each additional section	Two sections	Add for each additional section
600	0.022	0.018	0.028	0.015
700	0.030	0.025	0.037	0.020
800	0.040	0.032	0.048	0.027
900	0.051	0.040	0.061	0.034
1,000	0.063	0.050	0.075	0.042
1,100	0.076	0.060	0.090	0.050
1,200	0.090	0.072	0.107	0.060
1,300	0.105	0.085	0.126	0.070
1,400	0.122	0.102	0.147	0.082
1,500	0.140	0.112	0.170	0.093

Standard "Vento" tappings are $2\frac{1}{2}$ inches, but the feed sections can be tapped 3 inches or $3\frac{1}{2}$ inches. Use tapping schedule given for wrought-iron coils. Bush the returns to one-half diameter of steam tap plus one pipe size. Not over 480 pounds steam per hour is condensed in one group.

Three-eighth-inch air valves are installed at each end of each group about 8 inches from bottom of sections.

The foregoing formulae for rise in temperature and B.t.u. transmitted are empirical, and of course will not agree absolutely with the curves in the back of this book; but as formulae are more convenient when compact, they are submitted as giving results very close to what may be expected.

Curves Nos. 1, 2, 3, 4, and 6 in the back of this book give the temperature rise and condensation under various conditions. If the temperature of steam or initial temperature of air required is not found in the curves, use the nearest one given and make correction for difference on the assumption that the temperature rise and condensation vary in direct ratio to the difference between temperatures of steam and entering air.

Use the "standard" spacing (5-inch center to center) unless otherwise instructed. The "narrow" spacing, which is 4⅝-inch centers, and the "wide" spacing, which is 5⅜-inch centers, are not to be used except under special conditions.

The free area for standard spacing is 44 per cent of the area of face; the narrow 37 per cent; and the wide 52 per cent.

The 40-inch high 9⅛-inch deep section contains 10.75 square feet.
The 50-inch high 9⅛-inch deep section contains 13.50 square feet.
The 60-inch high 9⅛-inch deep section contains 16.00 square feet.
The 40-inch high 6¾-inch deep section contains 7.50 square feet.
The 50-inch high 6¾-inch deep section contains 9.50 square feet.
The 60-inch high 6¾-inch deep section contains 11.00 square feet.

For example, if a 60-inch high heater is desired with 22 square feet free area: 22 ÷ 44 per cent = 50 square feet gross area ÷ 5 feet (high) = 10 feet = 120 inches wide ÷ 5 = 24 sections wide.

After size of heater is found by the free area method, check same by the B.t.u. method by estimating the total B.t.u. required and dividing same by the condensation; the B.t.u. per square foot per hour being taken from the curves and corrected for difference in temperature (same as outlined for correction of temperature rise), or estimated from the formulae given.

Hot water. With water at a mean temperature of 180° F. the rise in temperature with wrought-iron coils and the B.t.u. transmitted are about 75 per cent of what they would be with steam at 227° when the velocity of air leaving the coil, number of pipes deep, spacing, etc., are the same.

To get the same rise in temperature with incoming air same temperature, same sections, same depth, etc., the velocity of air will be 40 per cent of what would be estimated for steam at 227°.

Curve No. 5 gives rise in temperature and B.t.u. transmitted for "Vento" heaters.

For other temperatures make corrections for rise in temperature, etc., as outlined for steam, or take the B.t.u. transmitted as 75 per cent of that for steam at same air velocity, etc., and for same rise in temperature the air velocity for water will be 40 per cent of that calculated for steam.

With hot water, forced circulation must be used in fan blast coils.

If high-pressure steam is used, the rise in temperature and condensation are estimated on the principle that these quantities are in proportion to the difference in temperatures of steam and entering air.

High-pressure steam is not used except under special conditions.

Prime movers. When engines are used, which is seldom, they are vertical, single or double-cylinder. Engines are direct-connected where possible and are provided with throttling governor.

Motors, if direct-current, are direct-connected when speed of fan is 300 turns per minute or more. If current is alternating, the motor is belted to the fan or connected by a silent chain drive. Belts should be run with "loose" side on top.

Flange or flexible couplings are used for direct-connecting motors and engines.

Steam and return piping.

$$D = \sqrt[5]{\frac{LW^2}{KP}}, \text{ in which}$$

D = diameter of pipe in inches.
L = length of pipe in feet (one way).
W = pounds of steam per minute.
P = loss of pressure, usually one pound per 300 feet.
K = a constant as follows:

Diameters (inches)...........	1	2	3	4	5	6	7	8
K = ...	104	140	160	169	173	180	183	187

For steam above 30 pounds pressure pipe is made half the diameter given by the formula, and for pressures of 10 to 30 pounds main is made two-thirds that given.

Return main one-half diameter of steam main, and make it "wet."

Place the bottom of coil as high as possible above water line in boiler, pump governor, or trap; never less than 18 inches and preferably 24 inches.

AIR DISTRIBUTION SYSTEM

Trunk main system. Trunk mains are used for Cases I, II, and V, except where cone fan is used. Where continuous ventilation is not necessary or where air change is much greater than necessary for proper ventilation, this system is used for Cases III and IV, except for cone fans.

The following instructions are to be observed in laying out the duct systems:

Main duct at fan is to be made the same size as fan outlet, which has been given heretofore. This duct will be square. Refer to the equalization table given hereafter and note how many pipes 1-inch x 1-inch are given as being equal in carrying capacity to this main duct. Divide this number of 1-inch x 1-inch pipes by the capacity of the fan in cubic feet per minute. This will give a fraction which is the portion of a 1-inch x 1-inch pipe to be allowed for each cubic foot of air. Now multiply the amount of air delivered to the base of each flue by the distance of said flue from the fan (distance means the length of duct, adding equivalent for turns, etc.), and divide this product by the amount of air handled by the fan. This will give the "average distance" of all outlets from the fan. Next multiply the amount of air to each flue by the fraction above obtained in dividing the total cubic feet per minute by the number of 1-inch x 1-inch pipes in the main duct at fan. This will give the number of 1-inch x 1-inch pipes to be allowed to each flue. This number of pipes is subject to correction as follows: For *each one foot* by which the distance (including equivalent for bends) from fan to base of flue exceeds the "average distance" previously obtained, one-third of *1 per cent* is to be added to the number of 1-inch x 1-inch pipes previously allowed for each flue. If the distance is less than the "average distance" the correction is to be deducted instead of added.

Now refer to equalization table and find the size of square pipe equivalent to the corrected number of 1-inch x 1-inch pipes for each flue. This is the size of the branch pipe at the base of the flue. Add all the branches back to the fan on the equalization table, and if the work is correct it will add up the size of main duct you started with.

Take an example: Fan with 54-inch x 54-inch outlet to handle 28,000 C.F.M. 54-inch x 54-inch pipe = 21,000 — 1-inch x 1-inch pipes; 21,000 ÷ 28,000 = 0.75.

Outlet number	Distance from fan in feet	C.F.M.	C.F.M. times distance	Number 1 inch x 2 inch pipes
1	50	6,000	300,000	4,500
2	50	2,000	100,000	1,500
3	60	10,000	600,000	7,500
4	110	10,000	1,100,000	7,500
			2,100,000	

2,100,000 ÷ 28,000 = 75 feet (the average distance).

Outlet number	Distance to be corrected for	Amount of correction	Corrected number of 1-inch x 1-inch pipes	Size of branch
	feet			*inches*
1	−25	−375	4,125	28x28
2	−25	−125	1,375	18x18
3	−15	−375	2,125	35x35
4	+35	+875	8,375	37x37

The main to carry branches Nos. 3 and 4 would be 8,375 + 7,125 = 15,500 = about 47-inch x 48-inch, etc.

Rectangular pipes to be same area as square pipe when ratio of width and depth is not more than 3 to 1. When this ratio is greater, add to area as follows: 10 per cent for a ratio of 4 to 1, 20 per cent for a ratio of 6 to 1, 30 per cent for a ratio of 10 to 1, etc.

If round pipes are used in some places the diameter of same = 1.10 times side of square pipe.

If round pipes are used throughout they can be handled just as we handle square pipes, for the equalization table applies to round as well as square pipes, but not to both at the same time.

In starting from the fan it is only necessary to make diameter of main pipe 10 per cent more than side of fan outlet.

Plenum chamber. Section of plenum chamber to be large enough to produce a velocity of not over 250 feet per minute across it, and should be as nearly square as possible.

Velocity in ducts from chamber to be about 800 feet per minute for cone fans and from 900 to 1,200 for steel plate and other fans.

By-passes, etc. By-passes around heating and tempering coils to be not less than 10 per cent nor more than 15 per cent of the gross area of the coil when they are provided with thermostatically controlled dampers. By-passes under heating coils of plenum chamber and double-duct systems have no dampers and should be not less than 25 per cent of the gross area of the coils.

Vertical flues and registers. Velocity in vertical flues to registers to be about 600 feet per minute, and through registers to be 200 feet through gross area, which gives about 300 feet over the *net* area. When air is admitted over 10 to 12 feet above the floor the speed through registers may be increased to 400 feet per miniute of net area. When floor registers are used the speed through them must not exceed 2 feet per second.

Resistance of ducts. The following formula, which is accepted as good practice, is used:

$$P = \frac{lV^2}{25,000d}, \text{ when}$$

P = loss of pressure in ounces per square inch.
l = length of pipe in feet.
V = air velocity in feet per second.
d = diameter of round duct in inches.

To reduce ounces to inches of water multiply by 1.73.

Should the duct be rectangular the size of equivalent round duct is found by the formula:

$$D=\sqrt[5]{\frac{32a^3b^3}{\pi^2(a+b)}},$$

when D = diameter of round duct, and a and b = the dimensions of rectangular duct. The resistance can then be figured as for a round duct.

The following formula is more generally used:

$$P=\frac{KSV^2}{A},$$

in which the symbols are the same as used above except:

S = rubbing surface in square feet.
A = area of duct (regardless of shape) in square inches.
K = 0.00012 for galvanized piping.
K = 0.00022 for brick or concrete ducts.

Bends. Bends in square and rectangular pipe should be turned on a true circle; it is entirely practical to make them in this way. In case of round pipes the "crimped" one-piece elbows are not used, but they are made in sections. Number of sections will be the next even number above the square root of the diameter of the pipe in inches.

When so constructed the resistance of each elbow is equivalent to a certain number of diameters or (in case of rectangular ducts) widths, as follows:

Radius of throat to diameter or width of pipe	Equivalent number of diameters, or widths, of straight pipe
0 (square turn)	100
$\frac{1}{4}$	65
$\frac{1}{2}$	30
1	10
$1\frac{1}{2}$	6
2 and above	5

Great care must be taken to insure that air ducts run as directly as possible and that changes in relative dimensions, offsets, etc., are avoided, as each such change adds a small amount of friction.

Branches should in general be taken from the side of main and the depth of branch at main should be same depth as main and be connected to main as nearly tangent to main as possible.

Example: A 12-inch x 12-inch branch to be taken from a 20-inch x 48-inch duct, the branch at main to be $7\frac{1}{2}$-inch x 20-inch and the taper made to 12-inch x 12-inch before the 90° turn in the branch is started.

Dampers and deflectors. At each branch a deflector with easy and quick adjusting device should be provided. Deflector should be large enough to close branch completely. When this is not practicable, place a damper in the branch duct.

In exhaust piping (when exhaust fan is used) place damper in each branch duct.

EQUALIZATION TABLE

"A"	"b"	"A"	"b"	"A"	"b"
1	1	20	1,788	39	9,498
2	5	21	2,020	40	10,119
3	15	22	2,270	42	11,432
4	32	23	2,537	44	12,842
5	60	24	2,821	46	14,351
6	88	25	3,125	48	15,963
7	129	26	3,446	50	17,678
8	181	27	3,788	52	19,499
9	243	28	4,148	54	21,428
10	316	29	4,528	56	23,468
11	401	30	4,929	58	25,620
12	498	31	5,351	60	27,886
13	609	32	5,793	62	30,268
14	733	33	6,256	64	32,768
15	871	34	6,741	66	35,388
16	1,024	35	7,247	68	38,131
17	1,191	36	7,776	70	40,996
18	1,374	37	8,327	72	43,988
19	1,573	38	8,901	74	47,106

Column "A" is the diameter or side of the square pipe in question.

Column "b" is the number of 1-inch diameter or 1-inch x 1-inch square pipes equivalent to the pipe in question.

Example: If a 12-inch diameter pipe will carry a certain amount of air a certain distance with a certain loss of pressure, there would be required 498 1-inch diameter pipes, or 498 ÷ 88 = 5½ 2-inch diameter pipes, to carry the same amount of air the same distance with the same loss of pressure, or 498 1-inch x 1-inch pipes would have the same carrying capacity as one 12-inch x 12-inch pipe, etc.

A more extended table of this kind is given in Trautwine's Pocket-book under the heading of "Square Roots of Fifth Powers."

The formula is:

$$N = \sqrt{\left(\frac{A}{b}\right)^5}, \text{ when}$$

A = diameter if round, or side if square, of larger pipe.
b = diameter if round, or side if square, of smaller pipe.
N = number of smaller pipes to equal in carrying capacity one large pipe.

Air washers. Air washers are installed except in very unusual cases. In any event the apparatus is arranged and designed for the future installation of an air washer.

Most of the standard makes of washers and eliminators are about 8 feet total depth and the cross section is such as to give through them about 500 feet per minute velocity, excluding the portion cut off by the settling tank.

A good washer will saturate the air passing through it to 60 to 70 per cent of the dew-point. It is desirable to carry as much moisture in the air of the rooms as possible, to avoid condensing same on windows. The maximum percentage of saturation that can be carried to avoid such trouble appears to be about *a mean proportional between the inside and outside temperatures.* Thus with 70° inside and 10° outside this percentage of saturation would be (70 + 10) ÷ 2 = 40 per cent.

Frictional resistance. The following data covering a well-known air washer are taken as representative of the standard makes:

Velocity, feet per minute	In washer proper	In eliminator	Total
450	0.10	0.14	0.24
500	0.12	0.17	0.29
550	0.13	0.21	0.34
600	0.14	0.24	0.38
650	0.19	0.26	0.45

The friction is inches water gauge.

Preferable velocities. A speed of 450 for small washers to 550 for large ones is used as a standard.

Pumps. Each washer has a separate centrifugal pump, driven by a direct-connected motor used for no other purpose.

The following table is used as a guide in selecting pumps and motors:

C.F.M.	Suction	Discharge	Speed	B.H.P.
	inches	*inches*		
5,000	2	1½	900	1¼
10,000	2½	2	900	1¾
15,000-25,000	3	2½	750	2¼
30,000-50,000	3	3	750	3½
55,000-70,000	3½	3½	650	4
80,000-100,000	4	4	650	4½

There is considerable variation in the speeds and B.H.P. of pumps of the various makes, therefore when laying out the wiring the motors are wired for about twice the B.H.P. given.

Temperature losses. The loss in temperature of the air passing through an air washer is capable of rather exact determination for a given set of conditions, but conditions are so variable that the worst conditions that may be expected are used as the basis of calculation.

It has been found in practice that the loss in temperature is 8½° F. for each grain of moisture absorbed per cubic foot of air. It is the moisture absorbed that is the uncertain part. The following example will illustrate: Inside temperature 70°. Outside air 0°. Outside humidity 50 per cent. Maximum humidity that can be carried is 70 ÷ 2 = 35 per cent. At 35 per cent saturation and 70° each cubic foot of air contains 2.8 grains. We may assume that the air will be 80 per cent saturated on leaving the washer. Outside air at 50 per cent saturation and 0° contains 0.25 grain per cubic foot. Now 2.8 − 0.25 = 2.55 grains moisture absorbed by each cubic foot of air. By figuring the heat required to evaporate this 2.55 grains it will be found that it is just sufficient to drop the temperature 7.6°. But there is a further loss due to cooling effect of the water, etc., making the total loss 8½° for each grain evaporated per cubic foot.

We had 2.55 grains evaporated and our temperature loss would be 2.55 × 8½ = 21.6°. Since each cubic foot of air at 80 per cent saturation is by our hypothesis to contain 2.8 grains water, the amount of water at 100 per cent saturation would be 2.8 ÷ 80 = 3.50 grains. The temperature of air required to maintain a dew-point of 3.5 grains is 45°, which is to be the temperature leaving the washer. Our tempering coil must then raise the air to 45° + 21.6° = 66.6°, and our heater coil must raise it from 45° to whatever temperature we have assumed at the fan.

In view of the varying outside air conditions it is the practice of the office to have sufficient tempering coils (not less than three sections deep) to raise air from minimum outside temperature to about 67½° and have it under accurate thermostatic control, and assume a temperature loss of 17½° in passing through the air washer.

Automatic control of coils when air washers are used is discussed under that heading.

Double inlet fans. It has been found that so long as the area of the inlet is smaller than the area of the outlet the capacity of the fan varies directly as the cube of the diameter of the inlet. A fan with two inlets will handle twice as much air as with one inlet of the same diameter, provided the "equivalent" of the two inlet areas is not greater than the outlet of the fan.

If we had a fan the standard inlet to which is, say, 60-inch diameter, and wanted to put two inlets and have the capacity of the fan remain the same, the diameter of each inlet should be $60 \div \sqrt[3]{2} = 48$ inches. In other words, two 48-inch diameter inlets are equivalent to one 60-inch diameter inlet. The horsepower for the fan would not be materially changed by this change in inlets.

If we should take the fan above, in which the one 60-inch diameter inlet is about the same area as the fan outlet, as is usually the case, and put another inlet of the same size, the capacity of the fan would be increased by $\sqrt{2}$ as a multiple. It would not be doubled as above, because the equivalent of the two 60-inch inlets is much larger than the standard outlet. The pressure would be doubled, the capacity increased nearly 50 per cent, and, as the power varies as the product of pressure and capacity (assuming the efficiency to remain the same), the power would be increased by three times.

Shop testing of fans. Shop tests of fans are not now required to be made in the presence of a representative of the office except when a style of fan is to be used upon which the office has no accurate data based upon a shop or other satisfactory test under conditions applicable to the case in question. The standard method of specifying a fan when such test is required is to state the peripheral velocity of wheel, the minimum diameter of wheel, the maximum brake horsepower, and the capacity; and, if required by structural conditions (such as ducts of a given size to which connections are to be made), the size of inlet or outlet, as the case may be, together with any other necessary dimension, is specified.

The total friction loss is carefully estimated; and, in testing, the outlet is fitted with a straight pipe about 50 feet long of same size as fan outlet. A blast gate made of slats not over 2 inches wide is placed at the end of the pipe. The fan is then run at the peripheral velocity specified. The Pitot tube is inserted about 25 feet from the fan and the slats in the blast gate are withdrawn until the *average* static pressure at the Pitot tube is equal to that specified (allowance being made for friction between fan outlet and Pitot tube according to formulae hereinbefore given). When these conditions are adjusted, the capacity and power are measured.

Capacity is measured by high-speed anemometer at end of pipe just inside the blast gate, and is checked by the Pitot tube. Ordinarily, measurements made at the inlet are useless on account of the whirl of the air giving unreliable readings, but sometimes reliable anemometer readings can be made on the inlet side, as in the air intake to cold-air room, etc.

Power is measured in the most convenient and accurate manner. It is generally preferable to have the fan driven by the motor that is to run it after installation, measure input to motor, and correct for efficiency and transmission loss.

The Pitot tube used by the office has a foot about 8 inches long, with an outer tube $\frac{5}{8}$-inch diameter and an inner tube $\frac{5}{16}$-inch diameter. The inner tube is turned against the current of air and at the U tube registers the dynamic pressure. This inner tube is continuous. The outer tube has a $\frac{1}{64}$-inch diameter hole on each side about 5 inches from the toe to receive static pressure and at the heel a $\frac{5}{16}$-inch tube runs to the same U tube as the inner tube, and, being connected to the opposite leg, the air velocity pressure can be read on the U tube. A "Y" may be inserted in the rubber connection and run to another U tube to read static pressure.

The outer tube at the toe is about $2\frac{1}{2}$ inches shorter than the inner tube, and a bevel (of a piece of cast brass or solder) is made for this length and ground until the end of the inner tube comes to a sharp edge.

All tubes are brass and the whole burnished smooth; and they must be tested statically for leaks.

A tube as above described, carefully made, will give reliable results. The writer has tested such a tube by revolving it on a shaft in still air and found readings exactly as calculated.

Vacuum systems. Mechanical vacuum systems, i.e., those having a vacuum pump attached to the return mains, are installed by the office only when exhaust steam is intended to be used for heating, or when a district heating service using this kind of system is available. In the latter case it is customary (except in the largest buildings) to install a 2-pipe system, with a special arrangement of the return valves at the radiators, so that it will operate as a gravity-return system from boilers installed in the building, or as a vacuum system when the outside service is used. The steam and return mains are proportioned for a gravity-return 2-pipe system.

The vacuum valves on the return of the radiators are of the automatic type, designed to pass air and water readily, but only a minimum amount of steam.

The pumps for producing the vacuum are the ordinary type of vacuum pumps having an automatic control of the vacuum carried in the return at the pump by controlling the steam supply to the pump. Pumps are installed in duplicate, and are invariably steam-driven.

The pumps discharge into an air-separating tank so located that the water will flow to the boiler feed-pumps through the feed-water heater by gravity. No definite rule can be given as to the size of tanks. About 1 cubic foot capacity to 2,000 square feet of radiation would be conservative, giving a tank 18 inches diameter by 24 inches long as a minimum. A 2-inch vent line should be carried to the atmosphere to allow the air to escape.

The make-up water for the boilers should be fed into the inlet of the pump; but there should be a make-up feed connection to either the air-separating tank or the feed-water heater, controlled by a float valve, to insure water for the feed-pumps in the event that the make-up valves at the pump inlets should be neglected.

The steam and return mains are sloped in direction of flow when possible. The base of each riser and the ends of mains are dripped into the return through a special valve, same as is used on radiator returns; but if the building is less than seven stories high the drips at base of risers may be safely omitted.

The return mains are usually not covered unless necessary for temperature control.

It is not considered advisable to lift the water of condensation, but it can be done successfully if a separate return main is run for the low radiators. In the post office at New Orleans, La., the return main is at the first-floor ceiling and takes care of radiators about 9 feet below, and operates satisfactorily.

The following sizes of steam and return mains are reliable for the Webster system. The quantities given are in pounds condensation per hour, and the distance is from the engine to the heater, one way:

Diameter of pipe		0-200 feet	200-400 feet	400-600 feet	Coil connection (steam)
Steam	Return				
inches	*inches*	*pounds*	*pounds*	*pounds*	*pounds*
¾	½				17
1	½				29
1¼	¾	51			51
1½	¾	73	52		73
2	1	160	116	87	160
2½	1	290	218	160	290
3	1¼	480	350	260	480
3½	1¼	730	540	410	
4	1½	1,050	770	580	
4½	1½	1,340	1,040	785	
5	1½	1,890	1,380	1,050	
6	2	2,900	2,325	1,450	
7	2	4,650	3,500	2,600	
8	2½	6,700	4,950	3,780	
9	2½	8,750	6,700	5,100	
10	3	11,600	8,750	7,000	
12	3	17,500	14,500	11,600	

NOTE—The sizes of steam mains for vacuum systems as given in the above table will give about ½ pound back pressure at the engine.

When estimating pipe sizes for direct radiation allow a condensation of 0.3 pounds per square foot per hour and proceed with the table.

When blast coils are on the system, the pounds of water per hour equal the total B.t.u. per hour put into the air, divided by the latent heat of steam, which at atmospheric pressure is 965.

Pumps. Sizes of vacuum pumps for vacuum systems may be found as follows: "Factor" equals 100 times the number of water-seal motor valves plus the actual square feet of *direct radiation.* In case of indirect radiation, or blast coils, reduce the radiation to equivalent direct surface by multiplying the actual square feet by the B.t.u. condensation per hour and dividing the product by 250 (the usual condensation of direct radiation in B.t.u. per square foot per hour).

After the "factor" is found refer to the following table and choose the pump corresponding to the "Factor."

In the table make the steam, exhaust, and discharge pipes the size given. Make the suction the size of the main return and bush at the pump to size given. All pumps are single-cylinder double-acting.

Size of pump Steam Water Stroke	Steam	Exhaust	Suction	Discharge	Factor	Floor space
inches	*inches*	*inches*	*inches*	*inches*		*inches*
4 x 4 x 5					6,830	
4 x 4 x 6	3/8	1/2	2½	2	7,270	11 x 34
4 x 4 x 8	3/8	1/2	2½	2	8,000	11 x 34
4 x 5 x 5					10,680	
4 x 5 x 6	3/8	1/2	3	2½	11,350	13 x 36
4 x 5 x 8	3/8	1/2	3	2½	12,500	13 x 38
4½ x 5½ x 8	1/2	3/4	3	2½	15,125	13 x 38
4½ x 6 x 5					15,390	
4½ x 6 x 7					17,215	
4½ x 6 x 8	1/2	3/4	3	2½	18,000	13 x 38
5 x 6 x 10	3/4	1	4	3	19,390	18 x 50
7 x 7¼ x 10	1	1¼	5	4	28,250	18 x 52
6 x 7¼ x 10	3/4	1	5	4	30,600	19 x 54
7 x 8 x 10	1	1¼	5	4	34,410	18 x 52
6 x 8 x 12	3/4	1	5	4	36,620	19 x 54
6 x 9 x 10					43,627	
8 x 9¼ x 12	1	1¼	6	5	48,957	20 x 58
8 x 10 x 12	1	1¼	6	5	57,220	20 x 58
8 x 10 x 14					60,250	
10 x 12 x 12	1¼	1½	6	5	82,397	20 x 62
10 x 10 x 16					90,713	
10 x 14 x 16					122,500	
12 x 14 x 20	1½	2	10	8	133,000	
12 x 16 x 16					161,270	
14 x 16 x 20	2	2½	12	10	173,720	
16 x 18 x 20	2½	3	12	10	209,870	
16 x 18 x 24					233,640	
18 x 20 x 20	3	3½	14	12	271,410	

In the foregoing table the steam cylinders of the pumps are proportioned for about 100 pounds steam pressure. Pressures differing materially from this would require proportionally different steam cylinders.

Capacity of the water-seal motor valves:

One-half inch diameter, 45 pounds water per hour = 150 square feet direct radiation.

Three-quarter inch diameter, 150 pounds water per hour = 500 square feet direct radiation.

One inch diameter, 360 pounds water per hour = 1,200 square feet direct radiation.

Dunham system. This is a system of steam circulation using special thermostatic valves on return ends of radiators. The following sizes of pipes may safely be used. The quantities given are in pounds of condensation per hour, and the distance is from the boiler or engine, as the case may be, to the most distant radiator, one way:

Size of pipe		200 feet	400 feet	600 feet	1,000 feet	1,500 feet	2,000 feet
Steam	Return						
inches	*inches*						
1½	½	77					
2	¾	167	135				
2½	¾	312	250	217			
3	1	510	410	357	302		
3½	1	777	625	547	462	392	
4	1¼	1,097	882	780	660	557	490
5	1¼	1,970	1,610	1,420	1,202	1,030	910
6	1½	3,220	2,670	2,347	1,995	1,680	1,430
7	1½	4,770	3,970	3,530	3,010	2,570	2,280
8	2	6,730	5,670	5,045	4,780	3,830	3,200
9	2	9,370	7,540	6,730	5,787	4,940	4,340
10	2½	11,670	10,010	8,965	7,745	6,630	5,900

Coil connections are as follows:

Three-quarter inch will take 20 pounds water per hour = 80 square feet direct radiation.

One inch will take 38 pounds water per hour = 150 square feet direct radiation.

One and one-quarter inch will take 71 pounds water per hour = 284 square feet direct radiation.

One and one-half inch will take 120 pounds water per hour = 480 square feet direct radiation.

Each thermostatic trap has a capacity of 90 pounds of water per hour, equivalent to 300 square feet of direct radiation. Each trap has a ½-inch outlet into the main, the connection to the coil being either ⅜-inch or ½-inch as desired. Traps are made either angle or corner pattern.

The office does not adopt the practice of running a separate return system to take care of the drips from risers and mains.

No horizontal branch, either stream or return, is made less than $\frac{3}{4}$ inch. It is especially important to observe this if branch is to be buried in floor construction.

The pump sizes herein given for the Webster system would be applicable to any of this class of vacuum systems.

All special attachments necessary for the operation of the apparatus are required to be furnished by the contractor when a vacuum system is used by the office.

The specification for such a system must, of course, be somewhat general to permit free competition.

MECHANICAL SYSTEMS OF AIR REMOVAL

These systems are sometimes installed in the larger buildings where automatic temperature control is used, or in buildings where outside steam service operating on an atmospheric system is to be used. In the latter cases it has been found that the mechanical air-removal systems are usually acceptable to the district service companies. The office does not often use an atmospheric system.

The steam and return piping is laid out in exactly the same manner and with the same sizes as for a 1-pipe gravity-return system, and all connections are made in the usual way.

The exhausting apparatus for plants less than 2,500 square feet direct radiation, or its equivalent in indirect, is a water-operated vacuum pump. The water pressure should be over 20 pounds per square inch to insure satisfactory operation.

In larger systems where high-pressure steam is made, a steam jet is used to induce a partial vacuum in the air lines. Velocity of steam at jet should be about 900 feet per minute.

In systems above 2,500 square feet where no high-pressure steam is made a small vacuum pump driven by an electric motor, usually about $\frac{1}{4}$ H.P., is used.

The motor should have an automatic regulating device, and if water or steam is used there should be a control valve so arranged as to carry constant vacuum on the air lines.

The discharge line from the ejector or pump is led to the blow-off tank, or some such receptacle, and a vapor line of same size is led to the atmosphere to prevent creating a back-pressure.

Care must be taken in the grading of the air lines to insure that no pockets are sealed with condensed vapor. Each rising air line should have a gate valve.

In this class of systems, and also in the larger installations of the mechanical vacuum type, it is the practice of the office to divide the radiation into groups and to bring the air lines and vacuum return lines back separately, valving each at the pump or ejector. Proper adjustment of these valves will overcome the "robbing" of one group by another. The steam mains to the respective groups should be valved to correspond, if possible, but these valves need not be centrally located as in case of the valves on returns.

The amount of steam used by the ejector varies widely, some authorities reporting as little as one-tenth of 1 per cent, and others as much as 5 per cent of the total amount of steam condensed.

The following is a sample specification (all material and labor included) for attaching an air-removal system to a system of direct radiation where the radiation exceeds 2,500 square feet and no high-pressure steam is available.

SPECIFICATION

From the automatic air valves on all radiators and coils take $\frac{1}{4}$-inch connection and tie into $\frac{3}{8}$-inch horizontal arms which in turn are to be connected with the $\frac{1}{2}$-inch air risers. The $\frac{1}{2}$-inch air risers are to be run to correspond with the steam risers and connected with the 1-inch air main located on ceiling of basement.

The 1-inch air main to be run to correspond with the supply main. This main to be connected with the exhausting apparatus located in the boiler room. All air piping to be graded toward the exhauster, to be reamed, and joints put together with asphaltum, and when complete must stand a pressure test as hereinafter specified. All air risers and branch mains to be supplied with gate valves. All air pipe fittings to be of cast iron.

Exhausting apparatus. Furnish and install one electric exhausting apparatus arranged to be direct-connected to the shaft of a $\frac{1}{4}$-H.P. motor, having same provided with an automatic starting and stopping device, controlled and operated by the vacuum carried on the air line system.

Motor to be arranged direct-connected to the shaft of a vertical duplex vacuum pump having all its working parts enclosed and arranged with an oil pump of sufficient capacity to lubricate all of the pump and motor bearings when in operation.

Air piping system hereinbefore specified to be connected to the vacuum pump as directed, the discharge from the pump to be connected with the sewer as directed.

Automatic air valves. On each radiator or coil place one automatic air valve and connect same as above specified; valves to be adjusted by the contractor and to be left in complete adjustment.

Testing of entire apparatus. Contractor must test the entire heating apparatus, including all air, steam, and return pipes, radiators, and boiler, with air under a pressure of 30 pounds to the square inch; said pressure to be on all parts of the apparatus at one time, and when cut off from the testing apparatus or air pump must stand for 24 hours, at the end of which time the leakage must not be greater than 5 pounds; or, in other words, at the end of 24 hours the plant must show 25 pounds gauge pressure thoughout the system.

ESTIMATING DATA FOR HEATING AND VENTILATING APPARATUS IN NEW FEDERAL BUILDINGS

Cost of boiler. Take off 50 per cent from price list for American Radiator Company's "Ideal Cylindrical" steel boiler or Kewanee Boiler Company's "Century."

Labor to install and test patent steel boiler	$ 50.00
Furnace (down-draft) in place	500.00
Foundations, brickwork for boiler and pit in place, per M	20.00
Foundations, concrete for boiler and pit, per cubic yard	8.00
Stone coping for boiler pit per cubic foot, in place	4.00
Breeching and stack in place, per pound	0.08
Cast-iron base plate for stack, per pound	0.03
Direct steam radiators (all heights) set in place, but not connected per square foot	0.20
Painting and bronzing, per square foot of radiator	0.03
Highest grade radiator valves and air valves (steam), per radiator	3.50
Highest grade radiator valves and air valves (water) per radiator (two regular steam type radiator valves are used on each hot water radiator)	4.50
Air valves at ends of steam mains in place, each	0.50
Controlling gate valves in place on steam mains, 50 per cent off list on standard weight gate valves.	
Labor on one-pipe steam jobs, per radiator	6.50
Labor on two-pipe hot water jobs, per radiator	8.00
Freight and drayage, 3 per cent total cost of boiler, radiators, pipe, and fittings.	
Superintendence, 1 per cent cost of labor and material.	
Nonconducting covering for pipes and fittings, per square foot of radiation (this also includes the boiler and breeching covering)	0.10
Pipe and fittings, one-pipe steam, per radiator	7.00
Pipe and fittings, two-pipe hot water, per radiator	10.00
Return pipe trench and cover complete in place, per lineal foot	1.50
Blow-off pot with pipe and valves in place	50.00
Forty-gallon expansion tank in place with pipe	25.00
Thermometers in place, each	1.00

Sylphon damper regulator in place (water)........................ $20.00
Board and lodging for men, per day.............................. 3.00
Railroad fare for Federal jobs, average conditions............... 50.00
Profit, 20 per cent.

Detailed estimating. If a closer approximation of the cost of the apparatus than the foregoing is desired, each foot of pipe of various sizes should be taken off the drawings, together with each fitting, valve, etc., and the following prices applied:

High-grade radiator air valves in place, each...................... $1.25
Floor and ceiling plates, unions (brass, ground-joint, up to and including 2-inch), and standard wrought-iron nipples, in place:

Size *Inches*	Nipples	Unions	Plates
½	$0.12	$0.30	$0.12
¾	0.12	0.35	0.12
1	0.15	0.50	0.20
1¼	0.15	0.60	0.20
1½	0.20	0.85	0.20
2	0.30	1.25	0.30
2½	0.40	0.60-flanged	0.40
3	0.60	0.75-flanged	0.50
3½	0.75	0.90-flanged	0.50
4	0.90	1.10-flanged	0.50
5	1.25	1.50-flanged	0.50
6	1.75	1.90-flanged	0.50
8	2.40	3.00-flanged	0.50
10	3.00	4.50-flanged	0.50
12	5.50	6.75-flanged	0.50

One-inch brass swing check valve, in place........................ 1.00
Gate, globe, and radiator valves in place:

Size *Inches*	Screwed gate	Globe	Radiator
½	$0.75	$0.67	$0.88
¾	0.98	0.89	1.10
1	1.27	1.15	1.38
1¼	1.77	1.48	1.83
1½	2.32	2.16	2.41
2	3.38	3.36	3.85
2½	6.05	5.92	
2½	3.60-flanged	5.08-flanged	
3	4.55-flanged	6.72-flanged	
4	6.10-flanged	9.52-flanged	
5	7.60-flanged	14.79-flanged	
6	9.10-flanged	17.60-flanged	
8	15.90-flanged	30.75-flanged	
10	25.50-flanged	44.50-flanged	
12	35.25-flanged	63.20-flanged	

(For high-pressure work add 100 per cent.)

Lever safety valves, iron body, in place:

Two-inch	$2.00
Two and a half inch	3.50
Three inch	4.50
Four inch	7.00

Brass blow-off cocks, asbestos-packed, in place:

Three-quarter inch	4.00
One inch	5.30
One and a quarter inch	7.50
One and a half inch	9.50
Iron, asbestos-packed, blow-off cocks, 2-inch, each, in place	6.00

Standard cast-iron screwed fittings, in place:

Size, *Inches*	Elbows	Tees	Hangers	Wall and floor sleeves
½	$0.12	$0.12	$0.80	$1.25
¾	0.12	0.13	0.80	1.25
1	0.18	0.20	0.80	1.30
1¼	0.20	0.25	0.80	1.30
1½	0.25	0.30	0.80	1.40
2	0.32	0.40	0.90	1.50
2½	0.45	0.50	0.90	1.50
3	0.60	0.70	0.90	1.90
3½	0.80	0.90	1.00	2.25
4	0.90	1.05	1.00	2.50
5	1.30	1.50	1.25	3.25
6	1.75	2.00	1.25	3.50
8	3.20	4.00	1.50	3.75
10	5.50	7.00	2.00	4.00
12	8.25	11.00	2.50	

(For high-pressure work add 100 per cent to all except sleeves.)

Standard black wrought-iron pipe per foot, in place, not including fittings or cutting walls, low-pressure steam, standard conditions:

Inches	
Up to ¾	0.06
1	0.08
1¼	0.10
1½	0.12
2	0.16
2½	0.22
3	0.30
3½	0.35
4	0.40
5	0.55
6	0.70
8	1.10
10	1.40
12	2.00

(For high-pressure work add 100 per cent.)

All pipe over 2-inch to be cut in shop.

Nonconducting covering in place, with solid brass bands and painted two coats fireproof paint, take 50 per cent off the 85 per cent magnesia list. This will average per square feet radiation	$0.10
Covering on boiler and breeching, per square feet, in place	0.20
Cast-iron blow-off pot, 24-inch diameter by 36-inch deep, net f.o.b. factory	25.00

One hundred pound pressure, standard design, horizontal return-tubular boilers, with all castings, will average f.o.b. factory the following prices, which must be increased at least 25 per cent for Government work:

Boiler *Inches feet*	Price	Setting and foundation in place
42 x 12	$300.00	$228.00
48 x 12	350.00	300.00
48 x 14	400.00	325.00
54 x 16	475.00	350.00
60 x 16	600.00	400.00
72 x 18	850.00	475.00

Down-draft furnace attached to horizontal return-tubular boiler will cost	600.00

To get freight, take weight of radiation at 7 pounds per square foot, and get weight of boiler out of catalogue, adding 25 per cent for down-draft furnace. To this total add estimated weight of pipe, fittings, and valves, based on same weighing 100 pounds per radiator. When estimating on freight call 5,000 square feet of direct radiation a car-load, and 36,000 pounds of pipe a car-load.

Take freight on Government job at $0.20 per 100 pounds, and drayage at $3.00 per ton.

Galvanized ducts, etc., in place, per pound	0.12
Registers, take 60 per cent off Tuttle and Bailey's list.	
Special valves on return ends of radiators, the receiving tank, the automatic vacuum and relief valves on receiving tank of atmospheric systems such as the "Dunham," per radiator	10.00

This figure is about correct for the Webster Modulation system and the Thermograde system, and should also cover the cost of all so-called "Vapor" systems.

For placing registers, each, add	1.00
Labor erecting ordinary indirect stack, each	5.00
Cast-iron pin indirect, delivered in basement, per square foot	0.20
Blast coils, per lineal foot in place on foundations, exclusive of freight	0.12
(To get weight multiply lineal foot by 3.)	
Engine and fan foundations in place, including excavation, per cubic yard	8.00
Full housed steel-plated fans in place on foundation, exclusive of freight and foundation:	
5 feet 0 inch	250.00
6 feet 0 inch	300.00
7 feet 0 inch	400.00
8 feet 0 inch	550.00

For handling fans and heating coils and placing on foundation, allow for labor, per ton	$12 00
Standard galvanized-iron air washer complete in place, exclusive of freight, foundation, and water pan:	
Capacity per minute, cubic feet:	
15,000	900 00
20,000	1050 00
25,000	1250 00
30,000	1500 00
40,000	2000 00
Air washer complete, including air-washer pump and motor complete, f.o.b. factory, per 1,000 cubic feet of air capacity specified	45.00
Erection	160.00
Freight and drayage	100.00
Brickwork in cement, per M in place	20.00
Trench plates in place, fitted and painted, per pound	0.05
High-pressure all-steel water-tube boilers, Government specification, and tested complete in place and set, but no pipe work or breeching, per H. P.	20 00
Feed water heaters in place on foundation, no pipe work, per H.P.	1 50
Boiler feed pump, 6-inch x 4-inch x 6-inch, with drip pan, brass fitted, in place on foundation, no pipe work	150.00

In estimating the cost of vacuum systems it will be safe to assume for the average Federal building that each vacuum pump on its foundation, complete, will cost $350.00, as the size will average 10 inches x 12 inches x 12 inches. Take the special valves on return end of radiators at $6.00 each in place. This allows for valve and return piping, but not for royalty.

For air line systems (no royalty) allow $5.00 per radiator for air valve and air piping. Electric air exhauster, $400.00 in place.

When royalties are charged for the above systems, they will average 10 cents per square foot of radiation. Water-operated exhausters cost $150.00 each.

In estimating cost of first-class automatic temperature-control systems, allow $26.00 for each thermostat, $22.00 for each damper controlled, and $10,00 for each steam or water valve controlled.

A hydraulic pump will handle fifty thermostats if necessary, but in the larger jobs an electrically-operated air compressor is used.

A hydraulic air exhauster is used on "Paul" systems with 2,000 square feet direct surface; above that, electrical or steam exhausters are used.

Especial attention is called to the fact that the foregoing figures are correct for certain special conditions in new Federal buildings, but are not applicable under all conditions. Used with judgment, they give accurate results.

PLUMBING, DRAINAGE, AND WATER SUPPLY

Before the acquisition of property upon which a Federal building is to be erected, a local engineer is employed to prepare a survey of the site and note thereon the size and location of all sewers and water and gas mains; also the elevation of the inverts of the sewers below or above city datum.

In order to determine from the survey whether the sewers available are sufficiently low to drain plumbing fixtures to be located in the basement, the first step is to decide which way the building will face, and then find the elevation of the top of the street curb midway of the lot; assuming that, as usual, the basement floor will be established 6 feet 6 inches below that level, and that the basement toilet-room will be located in the furthest corner of the building from the sewer it is decided to enter. The soil pipe in this toilet-room is assumed to be 8 inches to center below the basement floor at the start, and a grade of $\frac{1}{8}$-inch in 1 foot fall is assumed for the measured run from the basement toilet-room to the sewer. The estimated fall plus the 8 inches above noted is subtracted from the assumed basement floor elevation, and comparison of the result with elevation of the center line of the city sewer will show at once whether it is feasible to enter the sewer selected, and, if not, whether any of the other adjacent sewers may be used.

If it is found to be impracticable to enter any sewer which will serve basement fixtures, the architectural draftsman is so advised, and he arranges to place all plumbing fixtures on an upper floor.

If there are no public sewers the local engineer who prepares the survey ascertains and reports whether any sewers owned by private citizens are in the vicinity of the Federal property, and if such exist, gives all data in connection therewith and states whether permission to connect could be secured. If satisfactory service can be obtained at a suitable yearly rental, the building wastes are discharged into the private sewer.

In the event there is neither a city nor a suitable private sewer, the engineer reports whether the government can install its own sewer through the city streets to some outfall where nuisance will not be created at the point of discharge; and if such a sewer is feasible he submits a drawing showing the proposed route and profile.

The government will not build its own sewer unless the city will grant an irrevocable license to install and control same.

In the event no public or private sewers exist, and no feasible route or outfall can be secured, the engineer reports whether a cesspool would be feasible, and describes the manner of constructing cesspools in that locality.

If there are neither city nor private sewers, and on account of a clay soil a cesspool is not feasible, the engineer reports whether there is near the building a small creek or normally dry ravine into which it would be possible to discharge the effluent from a septic tank without any filtering. Before resorting to the last expedient special permission is always obtained from the local authorities, who are advised that the effluent from a septic tank is very offensive to eye and nose.

In a very limited number of cases it is found that there is no sewer of any description and that none can be constructed; that a cesspool is not feasible, and that no point of discharge can be secured for a septic tank. Under these adverse conditions a septic tank is installed and the effluent is discharged by gravity only (due to the level ground of site) into subsoil drains surrounded by gravel laid about 14 inches below the surface of the ground.

The office is very reluctant to employ either a septic tank or a cesspool, and rather than do so will go to heavy expense in installing a sewer for exclusive use of the Federal building.

In designing a sewer the following basic data are used:

Sewer must never be less than 8-inch diameter, and (except one length outside of each manhole where it passes under car tracks, and at the outfall into a stream or river where the sewer is constructed of extra-heavy cast-iron) it must be of salt-glazed earthenware pipe, with joints made with an oakum gasket and one-to-one Portland cement and sand. Manholes are placed at each change in direction, and on straight runs are spaced 300 feet apart. Manholes are made 3 feet 0 inches inside diameter, and 9-inch-thick walls of sewer brick are used until manhole is 12 feet 0 inch deep; and over this 13-inch walls are used. The floor of manhole is concrete and is made 12 inches thick, with a channel hollowed out in the concrete to connect the inlet and outlet pipes. The floor is made on an angle to grade to this open channel. In manholes over 6 feet 0 inch deep iron ladders are installed. All manhole covers are solid, and with frame weigh not less than 315 pounds each.

The earth cover over sewer is never less than 18 inches deep and is made at least 3 feet 0 inch deep if possible. The sewer outfall at the stream or river where earth banks exist is protected by a dwarf wall of concrete.

Both sanitary wastes and roof water are conveyed in this sewer and a grade of ¼-inch in 10 feet 0 inch is desirable, but if conditions demand 1 inch in 10 feet 0 inch may be used. A velocity of over 8 feet per second is not allowed if it can be avoided without great expense for excavation.

Septic tanks are constructed on the following basic data:

Tanks are made rectangular and with a depth of liquid of not less than 5 feet 0 inch; and are of sufficient capacity to contain all the sewage discharged by the building for a period of 8 hours based on 100 gallons per day per occupant, or on 500 gallons per plumbing fixture per day if number of occupants is not known.

Tanks are constructed of concrete with walls and bottom 8 inches thick and with 6-inch-thick reinforced concrete cover with manhole. While the present practice commercially permits the use of open tanks, covered tanks are demanded by conditions in connection with the buildings under discussion.

Cesspools are generally constructed of hard-burned common brick, and are usually 8 feet 0 inch to 10 feet 0 inch in diameter and 20 feet 0 inch deep. If there is a sand or gravel stratum, the walls of cesspool are run down into same 3 or 4 feet, or far enough to penetrate ground water if same exists. Where ground water stands at a definite level in the cesspool, as is sometimes the case in western Maryland and Pennsylvania, the inlet pipe is turned down below the level of ground water to favor a septic action. A solid 315-pound manhole frame and cover is placed on cesspool and a vent pipe is taken from near top of cesspool and run up inside of building to above the roof.

When cesspools are used an effort is made to have all plumbing fixtures located on upper floors, as fixtures in basement will overflow by reason of filling up of cesspool.

It hardly seems credible that cesspools would be tolerated in any civilized community, but a large number of prosperous towns still cling to their use.

For use in cases where a combined system of sewers is provided in a city, and also in proportioning a drainage system for roof water and sewage or for roof water only, the following table, which is sufficiently accurate for all practical purposes, was made some years ago by the writer and has ever since been used with success by the office. It is based on the very conservative data of sewer running full when the rainfall is at the rate of 6 inches per hour, and on a speed in sewer of approximately 3 feet per second, the minimum speed permissible, and which requires a grade of not less than 1 inch in 10 feet 0 inch for all sizes up to 6 inches. Even in the larger sewers the grade is made not less than 1 inch in 10 feet 0 inch. A speed of 8 feet per second should not be exceeded in a strictly sanitary sewer, as an intermittent flow, such as these sewers are subjected to, will cause the liquid to deposit the solids held in suspension.

Area of roof *Square feet*	Diameter of pipe *Inches*
1,000	3
2,000	4
3,000	5
4,500	6
9,000	8
16,000	10
25,000	12
35,000	14
50,000	16
75,000	18

The distance between outlets in roof gutters should not exceed 60 feet 0 inch. Three-inch diameter downspouts from main roof may be used with safety.

When a drainage system is proportioned for disposal of sanitary wastes only, the office employs the following data:

	Connection *Inches*
Water-closet	4
Siphon jet slop sink	4
Ordinary slop sink	3
Kitchen sink	2
Siphon jet urinal bowl	2
Shower-bath	2
Bath-tub	1½
Single lavatory	1½
Two to twelve lavatories	2

Maximum number of water-closets to connect to various size pipes:

Size of pipe	Number of water-closets
4	12
5	24
6	42
7	70
8	105
10	200
12	355

Small fixtures in number not exceeding twice the number of water-closets given above may discharge into the lines without the size being increased.

One-quarter of an inch per foot is the standard grade for which recessed drainage fittings are pitched, but this can not be obtained in fireproof buildings when pipes are run in floor construction, and said pipes are run practically level and give good service.

When a combined system of sewers is in use in a city, it is important to protect the fixtures located in the basement of the Federal building from overflow which may result from backing up of the city sewers. This is accomplished by connecting the drain pipe serving the basement fixtures independently to the main house drain and installing near the point of junction a back-water valve and a hub-end gate valve on the basement toilet-room drain. Then if city sewer backs up the basement fixtures may be cut off and the roof-water continue to enter city sewer, and the fixtures on the upper floors be kept in use. A $\frac{3}{4}$-inch diameter vent pipe is taken from the back-water valve or near same, and connected near ceiling of basement to a vent pipe so as to relieve the piping system of air when the back-water valve closes. The back-water valves are specified to stand open normally. Basement window areas are protected with back-water cesspools, or back-water traps.

Under adverse conditions, where city sewers are inadequate and overflow constantly, or where the fixtures in basement must be located below any city sewer, then the "Shone" or equal type of sewage ejector is used, together with a motor-driven air compressor and air tank for the purpose of automatically discharging the low-level sewage into the city sewers. These devices have proved most satisfactory in service, with practically no shut-downs for repairs.

Where sanitary sewers exist in a city, or a cesspool or septic tank is in use and there are no sewers for the disposal of rain water from roof, the roof-water is discharged on the surface of the ground. As a general rule, the discharging of roof-water on driveway in rear of building is prohibited on account of danger to horses during freezing weather. The down-spouts are nearly always brought down on inside of building and discharge on drip stone on a grass plot, or enter rectangular cast-iron gutters set in sidewalk with covers flush with surface of walk. These cast-iron gutters discharge into street gutters.

In all cases where downspouts are collected in the roof space or in an unheated attic, the pipes exposed in said space are covered with 2 inches of hair-felt with a canvas jacket to prevent freezing.

When the local engineer who prepares the survey reports that ground water exists within 8 feet of the surface of the site, the practice of the office is to install around the exterior of the building an agricultural or subsoil drain consisting of 4-inch-diameter salt-glazed earthenware hub sewer pipe laid at a grade of $\frac{1}{4}$ inch to $\frac{1}{2}$ inch in 10 feet 0 inch and surrounded on bottom with a 3-inch bed and on both sides with a 6-inch bed of gravel or 2-inch broken stone. This stone or gravel fill is carried up to within 1 foot of grade and covered with hay or burlap, and then sodded over. The summit of the agricultural drain is made not less than 3 inches below basement floor, and the joints in the pipe are cemented on the bottom and half way around to maintain a channel. The upper part of the joint is open and covered with a layer of burlap.

The agricultural drains discharge into a brick manhole 3 feet 0 inch diameter with concrete bottom and manhole cover similar to a regular city-sewer manhole. The inlet pipe to manhole is provided with a cast-iron quarter-bend, turned down to form a water seal and prevent sewer air entering the sub-drains. The outlet pipe is provided with a back-water valve, and said pipe is connected to the building sewer.

As local and state ordinances do not apply inside the Federal lot line, the office is not hampered thereby in the design of plumbing and drainage systems, but outside the property limits complies with local regulations, such as those which prohibit discharging roof-water into sanitary sewers, or which require the installation of a running trap on main house drain. The office is strongly opposed to the last-named device, and installs it only under protest in towns which continue to cling to this antiquated expedient.

Cases are frequent where only sanitary sewers are in use, and it is necessary to drain into same the small basement entrance and window areas. Permission to do this is always readily granted by the local authorities.

If a basement entrance or window area is to be connected to the drainage system of building under basement floor, a cesspool without a bell trap is placed in the area and the pipe connection is brought into the building below basement floor and provided with a running trap with clean-out screw flush with basement floor. This trap prevents water being held in the cesspool and freezing (as with the common cesspool with bell trap), and also prevents the escape of drain air at this point when cesspool covers are removed.

If the area cesspools connect to a drainage system located on exterior of the building, as may be the case where separate storm-water sewers exist, the bell trap is omitted as before noted and a "P" trap is used at base of the vertical from the cesspool pipe.

As early as 1892 the writer urged upon the office the adoption of the end-vent or circuit system of plumbing, originated by William Paul Gerhardt, and also strongly advocated the omission of a running trap on the main house drain. The office accepted both improvements about 1894 and has used them continuously since that time with great success; and its example has undoubtedly had much weight in bringing about a wide adoption of the end-vent system and the consequent abandonment of the complicated back-venting systems.

In the early days of this advancement the office met with much criticism from local inspectors in various small towns where Federal buildings were being erected, but protests along this line are now so infrequent as to indicate that ancient history has been abandoned as a guide in the practice of plumbing.

In the end-vent system the soil pipes are extended up above the roof full size, as are the dead-end vents in most cases, and no traps are placed at the foot of the interior downspouts unless they open within 20 feet of a window.

The mains are carried close to the fixtures, and the dead ends to fixtures do not as a rule exceed 6 feet in length, which is equivalent to a developed length of 10 feet. These short dead ends receive sufficient oxygen to maintain the bacteria active.

The omission of the running trap and the generous size and number of vent pipes extending above the roof serve to create a positive current of air from the city sewer through the plumbing system and thus help to ventilate the city sewer, a very desirable feature. It is of interest to note that if a cleanout plug is removed on one of these systems at the base of a soil or waste stack, a strong and continuous current of air from the room into the pipe will be observed.

Siphon-jet water-closets and urinals are used exclusively. All traps on other fixtures are non-siphoning, except the floor drains from shower-bath stalls, which are always end-vented for protection against siphonage.

All soil, waste, vent, and drain piping below basement floor, and from building to cesspool, septic tank, or city sewer (if the latter is within 200 feet of the building), is extra-heavy cast-iron hub-and-spigot pipe with lead-caulked joints, either coated or uncoated. The fittings thereon are extra-heavy to correspond to pipe. No pipe below basement floor is less than 2-inch diameter.

Cleanouts are used on horizontal runs below basement floor and are located in brick or concrete manholes with iron covers set flush with basement floor. These cleanouts are located so that the piping system may be rodded to clear obstructions, and they are located not over 40 feet apart on straight runs.

Brass screw-jointed cleanout plugs are located at the base of all vertical soil, waste, and vent pipes, and at base of all vertical downspouts where same are connected to the drainage system below the basement floor. Similar cleanouts are used on horizontal soil and waste pipes in toilet rooms above the basement.

All soil, waste, and vent piping and all interior downspouts above the basement floor are made of standard galvanized wrought-iron or mild-steel pipe with cast-iron, recessed, screw-jointed, galvanized drainage fittings.

All brass pipe on sewer side of traps is iron-pipe size and thickness, and on fixture side of traps is brass tubing.

Water-supply piping exposed in toilet-rooms on face of marble work and at fixtures is nickel-plated brass pipe, iron-pipe size and thickness; and all other water piping is standard galvanized wrought-iron or mild-steel pipe. If demanded by the character of city water, brass pipe or lead-lined iron pipe is used.

All valves are standard weight; 2-inch and smaller are brass, and larger are iron body.

No running threads or long screws are permitted in jointing any pipe, and in lieu of same all-brass ground-joint unions, flange unions, or right-and-left couplings are used. No provision for expansion is made in any piping except hot-water piping over 100 feet long.

UNIFORM PLUMBING SPECIFICATION

About two years ago the Treasury, War, and Navy Departments decided to coöperate in designing a complete line of plumbing fixtures, and to require their respective contractors to furnish fixtures in strict accordance therewith. The result is the government publication entitled "Specification for Plumbing Fixtures, etc., for the Treasury, War, and Navy Departments," which may be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., at 35 cents per copy.

The board which prepared this specification has produced a document remarkable for both scope and accuracy, and has rendered a substantial service to sanitary engineers and to the manufacturers in this line of business. Engineers and architects who have had to hear and weigh the claims and counter-claims of representatives of various plumbing-material houses will undoubtedly appreciate the relief which the standardization brings.

The Treasury Department's representative on the board is Mr. H. M. Price, Mechanical Engineer, Office of the Supervising Architect.

The following is a brief description of the line of plumbing fixtures in general use in buildings under control of the Treasury Department:

All fixtures (except wash sinks in boiler room) are required to be *extra-heavy vitreous earthenware* of rugged design.

Closet bowls are required to weigh not less than 54 pounds in any case, and in most cases not less than 75 pounds.

The closet must be capable of passing the ink test in regard to flushing. This test requires that the interior surface of the bowl from water line up to flushing rim shall be smeared with ink, and that upon flushing closet the water level in the bowl must not rise, and it must be clearly demonstrated that the flush is reaching all parts of the bowl surface above the water line.

The closet must also be capable of discharging with one tank full of water 32 sheets of toilet paper spread out on the floor and one end balled up and placed below water line of bowl. The same number of sheets (loose) lightly balled up and dropped into bowl must also be readily cleared out with one discharge of the tank.

Slop sinks are of the siphon-jet type with flushing rim molded in the bowl, and are supplied with flushing tank and with combination hot and cold water faucet.

Urinals are siphon-jet type so designed as to contain a body of water in the bowl. For economy in water consumption, pull flush tanks constructed similar to water-closet tanks are used on urinals.

Lavatories are made with overflow molded in the bowl, and are provided with the ordinary brass chain and rubber plug. Self-closing faucets have not proved entirely satisfactory, and the "Fuller" or compression type of faucet is used.

Bath tubs are cast-iron, enameled inside and painted outside, and not less than 5 feet 0 inch long and 24 inches wide, with roll rim, and are provided with combination faucets and non-siphoning trap, and with either a standing overflow, or a common overflow and a brass chain and rubber plug.

All fire hose is 2-inch diameter, unlined, woven linen, Underwriters' hose, with 75 feet 0 inch of hose to each outlet. Each length of hose has a 12-inch-long brass nozzle with $\frac{3}{4}$-inch opening and necessary couplings, and is mounted on a first-class hose rack which allows hose to hang in vertical loops.

The shower-baths have a 5-inch diameter adjustable head, and are provided with a mixing valve so designed as to prevent scalding the bather. Floor drains for showers are cast brass, with removable bar strainer cover not less than 5-inch diameter.

All urinal stalls, shower-bath inclosures, and water-closet inclosures are light-colored marble, $1\frac{1}{8}$-inch thick.

The floor of toilet-rooms are terrazzo, with marble border having a sanitary cove cut in same. Marble wainscot $\frac{7}{8}$-inch thick is used in all toilet-rooms. Height for main toilet-rooms is 6 feet 0 inch, and 4 feet 6 inches for private toilet-rooms. Window and door trim in toilet-rooms is marble.

The minimum size of a private toilet-room in Federal buildings is 4 feet 6 inches x 5 feet 0 inch, which allows for the installation of a water-closet and a lavatory if entrance door is properly arranged and lookout ladder does not interfere. A larger room is provided if possible.

Toilet-rooms which are intended to contain a bath-tub, water-closet, and a lavatory are made 5 feet 6 inches x 8 feet 6 inches, if entrance door can be properly placed. Five feet by 8 feet is considered the minimum for first-class work. Water-closet inclosures for men are generally made 2 feet 9 inches to center and 5 feet 0 inch deep.

Inclosures for women are generally made 3 feet 0 inch clear inside and 5 feet 0 inch deep, and inclosure and entrance door extend to within 6 inches of the floor lines. Wherever possible, a retiring-room is provided for women in connection with their main toilet.

Main toilet-rooms are made as large as a due regard for economy will permit.

It is a practice to screen toilet-rooms opening off corridors so that occupants will not be within view when entrance door to toilet-room is opened. All toilet-rooms are provided with windows in exterior walls in order to obtain light and air.

In the carriers toilet-room of a Federal building the minimum number of water-closets provided is three; and in this room are also installed a slop sink, a shower-bath, and at least *one* urinal and *one* lavatory.

The proportioning of fixtures in a Federal building is solely a matter of judgment and experience, but as a rule one closet to ten persons is allowed in the smaller buildings, and one closet to from thirty to forty persons in the large buildings, similar to school-house practice.

The number of urinals never exceeds one-half the number of water-closets, and the number of lavatories is reduced to a minimum, generally not more than two being provided in a large toilet-room.

A slop sink is provided in connection with or adjacent to the first-floor lobby, and also in all main toilet-rooms except those assigned to women. Lavatories are provided in each office room if the appropriation for the building permits.

In the Philadelphia post office one general toilet-room containing 22 water-closets, 12 urinals, and 15 lavatories was provided for from seven hundred to eight hundred employees, and proved satisfactory.

A women's toilet-room is always provided in the post-office section of a building, and if building is two stories high or over a women's toilet-room is also provided on one of the upper floors, in the most inconspicuous location possible.

In laying out chases for the reception of the plumbing piping 12 inches of solid wall is left at the back of the chase in exterior walls and 9 inches in interior walls.

Minimum depth from plaster line to back of chase: 8 inches for 5-inch and 6-inch pipes, 6 inches for 3-inch and 4-inch pipes, and 4 inches for pipes smaller than 3 inches.

Width of chases: 12 inches for two 4-inch pipes, 8 inches for one 4-inch or 5-inch pipe, 8 inches for two 2-inch pipes. No chase is made less than 8 inches unless structural conditions demand, in which event a 4½-inch chase is made for one 2-inch pipe.

No chase is placed closer than 9 inches to a beam bearing, nor closer than 15 inches to a girder bearing, nor closer than 12 inches to any window or other opening.

Unless architectural reasons prevent, all soil and waste pipes are run exposed at ceiling of room below toilet-room.

All water pipes are run exposed in toilet-rooms, none being buried in floor or walls.

The raising of toilet-room floors to conceal piping is not resorted to unless the conditions absolutely demand that action.

WATER SUPPLY

Most of the cities in which Federal buildings are erected have a first-class water-supply system, serving water of a good quality and at a pressure sufficient to supply all fixtures provided; and the problem of water supply for the building is therefore merely the proportioning of piping to supply the fixtures and the fire hose.

When the normal city water pressure is in excess of 50 pounds, or where the mains are subjected to high pressure during fires, a pressure-reducing valve is installed in the building to protect the plumbing fixtures; and the street washers and fire hose are connected to the main supply pipe between the street main and the pressure-reducing valve.

In towns where there is no water-supply system, or where the water is of poor quality, careful investigation is made for the purpose of ascertaining whether it is feasible to sink a deep well from which all the water required for the building can be obtained. Such wells are usually installed by local contractors, who are required to guarantee a certain delivery during eight hours continuous pumping.

When there is much sand in the deep-well water, as in Texas and on the Pacific coast, the well is operated by an air lift, or the deep-well pump discharges into a cistern to allow the sand to deposit. From this cistern the triplex house-pumps take suction, and they discharge into riveted steel receivers of not less than 800 gallons capacity.

The old style of open-roof or attic storage tank is not used in Federal buildings except when conditions absolutely demand, as when the city water pressure is low during the day and can not supply the fixtures on the top story, but rises during the night sufficiently to fill an attic tank. Under these conditions the daily city water pressure is utilized to supply all the lower floors, and the upper floors are supplied by the tank without the necessity of pumping.

The requirements for fire protection for any Federal building practically govern the size of the main water-supply pipe, which is never made less than 2-inch diameter. For the smaller buildings it is assumed that only one line of fire hose will be in service at any one time, and for large buildings that all fire hose on one floor will be operated simultaneously. The area of a 2-inch pipe is allowed for each fire hose in service, and the main supply pipe to the building is made of a discharging capacity equivalent to the selected number of 2-inch pipes.

While the main water-supply pipes are approximated on the fire-protection service when the city water pressure is sufficient to supply all fixtures in the building, fire-protection requirements do not govern when a pumping plant must be installed, as the pumping plant is proportioned for the supply of the plumbing fixtures only.

At some Quarantine Stations pumps and piping are installed for fire protection only, and then the following basic data are used in proportioning the system:

Pressure at hydrant, 32 pounds; 90 gallons of water per minute; 100 feet of 2-inch hose with $\frac{3}{4}$-inch nozzle.

Under the above conditions the nozzle will throw water 50 feet horizontally and vertically, necessitating the spacing of hydrants 300 feet apart. The buildings at Quarantine Stations are seldom more than 40 feet high, and usually there are not enough attendants to care for more than one hose stream at a time. The piping is proportioned to keep the friction losses within a reasonable limit, and 2-inch hose outlets are usually provided.

Triplex pumps driven by gas engines are used for fire protection at Quarantine Stations. The size of gas engine is ascertained by multiplying the number of gallons of water per minute by the pressure at hydrant plus all friction losses (which are never less than 50 per cent of pressure at hydrant), and dividing the result by 800.

Where fire-protection service requirements do not govern, the size of main service pipe is based on the assumption that the maximum consumption of water will be at the rate of 500 gallons per day for each water-closet, urinal, shower-bath, lavatory, sink, and wall hydrant.

A terminal pressure of 8 pounds per square inch should be maintained at the highest fixture, and the drop in pressure in main service pipe (assumed to be 100 feet long) must not exceed 10 feet head. With this loss—

Size of service	Velocity in feet per second	Gallons in 24 hours
½	4	3,000
⅝	4	5,000
¾	5	7,200
1	4½	16,000
1¼	4	28,000
1½	5	42,000
2	6	86.000
2½	6½	144,000

The above table is sufficiently accurate for all practical purposes.

Where the city water pressure is low, say below 30 pounds per square inch, the piping is laid out and the pipe sizes carefully calculated with this in view. If a water filter is to be installed it is charged with a loss of pressure of five pounds.

Practice has fixed the size of branch water-supply pipes to the various fixtures as follows:

	Inches
Water-closet flush tank	½
Urinal flush tank	½
Slop sink flush tank	½
Slop and other sinks	¾
Shower-baths	½
Bath-tubs	½
Lavatories	½
Street washers	¾
Small heating boilers and hot-water heaters	¾

The branches to toilet-rooms containing three or a less number of fixtures are made ¾-inch diameter; more than three and not more than nine fixtures, 1-inch diameter; more than nine and not more than twenty-one fixtures, 1¼-inch diameter; and for from twenty-two to thirty fixtures, 1½-inch diameter.

The proportioning of branch water-supply pipes is a matter of experience and judgment, as it is based not only on the number of fixtures in the various toilet-rooms and on the group of toilet-rooms served by one branch or riser, but also on the number of fixtures that will be used simultaneously, a difficult matter to determine accurately.

As previously stated, the branch connections to fixtures are fixed by practice, and certain conservative sizes are established for branches to toilet-rooms containing various numbers of fixtures. The general practice is to allow, when flush tanks are used, that a ½-inch diameter pipe will serve any fixture, and in calculating the proper size of the branch main to a toilet-room, or of a riser to serve a group of toilet-rooms, it is assumed that from 25 to 50 per cent of the fixtures will be used simultaneously. The area of a ½-inch pipe is allowed for each fixture so used, and the branch is selected from an "Equalization of Pipe Area" table.

In a toilet-room containing eight fixtures with 50 per cent used simultaneously this would give the equivalent of four ½-inch pipes, or a 1-inch branch. With twelve fixtures the branch would be 1¼-inch, and with 50 per cent of the fixtures in use simultaneously a 1½-inch pipe would serve thirty-two fixtures.

For a very large toilet-room with many fixtures the branch pipe should be not less than 1½ inches, and not exceeding 25 per cent of the total number of fixtures installed should be considered as being used simultaneously.

For the calculation of branch supply pipes the water consumption of water-closets is well established. The standard flush tank is set 7 feet 0 inch above the closet, and under ordinary operating conditions it will discharge twenty gallons of water per minute into the soil pipe. The water consumption of urinals, lavatories, etc., is taken at one-half that amount.

The following table may be used in proportioning the piping when flushometers are to be used:

Water pressure	Water-closets			Urinals		
	Number of closets	Size of main	Size of valves	Number of urinals	Size of main	Size of valves
pounds		*inches*	*inches*		*inches*	*inches*
3½–10	1	1½	1½	1	1	1
	3	2		2–3	1¼	
	6	2½		4-6	1½	
15–30	1–2	1½	1¼	1–2	1	¾
	3–8	2		3-8	1¼	
	9–16	2½		9–12	1½	
31–50	1-4	1½	1¼	1–3	1	¾
	5–14	2		4–10	1¼	
	15–24	2½		11–16	1½	

The sizes given above are sufficient to supply all fixtures in a toilet-room with cold water, and no additional allowance need be made for lavatories, sinks, etc.

Flushing valves are not used except in the large buildings, nor where the normal city water pressure at the highest fixture is less than 10 pounds; and generally the limit is made 15 pounds to avoid large pipe sizes.

Water filters are used only where the conditions absolutely demand them. The specifications for filters to be used where water is very muddy require the maximum rate of filtration to be four gallons of water per minute per square foot of filter area, and in slightly muddy waters to be six gallons per square foot per minute. Under the conditions noted above, with city water of normal turbidity, during the test the filter must deliver the amount of water specified, and at the end of an eight-hour run the filtrate must be clear and must not contain free alum or any other coagulant used.

During the eight-hour test the filter must not require washing, and the drop in pressure of water passing through filter must not be greater than five pounds.

The filter must be easily operated, with as few valves as possible; and when reversing the flow to wash the filter the bed must not be carried out through the waste pipe.

The filter bed must be not less than 2 feet 6 inches deep, composed of clean, sharp, quarried granite or quartz ground to the proper fineness. Sea or river sand in the filter is not permitted. Two units are always installed, each a complete filter, and so fitted that the units may be used singly, in parallel, or in series. Filters are not used where the entire water supply of the city is filtered.

In proportioning filters, deep wells, and pumping plants, the number of occupants is ascertained for any given building, and the water consumption is based on a rate of 100 gallons per day per capita. Where the number of occupants cannot be ascertained with any accuracy, the rate of water consumption is based on 500 gallons per day for each plumbing fixture. This rate is established to cover the maximum demand on the system.

In the Philadelphia post office the city water pressure was sufficient to supply only the fixtures in basement and on first floor. The fixtures above first floor, numbering 140, had to be supplied by pumps, and on the basis given above this required 50 gallons of water per minute. Two triplex pumps, one 3-inch x 4-inch and one 4-inch x 4-inch, with a combined capacity of 50 gallons per minute, were installed. These discharged into a steel receiving tank 60 inches in diameter and 10 feet 0 inch high, in which was retained a body of air. These pumps have successfully supplied the fixtures for years.

In the Toledo post office a deep well was installed, with a capacity based on the installation of 68 plumbing fixtures to serve 300 occupants. On the rules previously given this would require 34,000 gallons a day for fixtures, and 30,000 gallons a day on the per capita basis. A mean of the above would require approximately 22 gallons per minute.

The well is 8-inch diameter and 502 feet deep, and on test delivered 25.8 gallons of water per minute. Before pumping, the water in the well stood 128 feet below the surface of the ground, and after pumping eight hours at the rate above noted it fell to 168 feet, rising again when pumping ceased.

A pump $3\frac{3}{4}$-inch diameter by 24-inch stroke was installed, which at 25 revolutions per minute delivers twenty gallons of water per minute into a tank against 30 pounds pressure. The pump was operated by a deep-well pump head driven by a 5-H.P. motor. A 3-inch cylinder with 4-inch-stroke air compressor was installed, driven by a 3-H.P. motor, and discharged into a galvanized-steel air storage tank with a connection to the air space of the main pressure tank.

The air tank was 18-inch diameter and 5 feet 0 inch long, with $\frac{3}{16}$-inch shell and $\frac{1}{4}$-inch heads, and the compression tank was 60-inch diameter, 26 feet long 0 inch and constructed with $\frac{5}{16}$-inch shell and $\frac{7}{16}$-inch dished heads. Rivets were $\frac{3}{4}$-inch diameter, spaced $2\frac{1}{8}$ inches center to center. Tank was tested to 100 pounds.

The gauge glass was 24 inches long, and the tank was provided with a 11-inch x 14-inch manhole located below the water line.

The calculation of the horse-power on the usual basis shows that with deep-well pumps considerable allowance must be made in motor for the weight of the suction rods in spite of the buoyancy of the water.

Thirty pounds in tank plus 168-foot lift equals approximately 110 pounds.

$$\frac{20 \times 110}{1700} = 1.3 \text{ actual horse-power.}$$

Taking the pipe friction at 50 per cent of the 110 pounds would require

$$\frac{20 \times 170}{1700} = 2 \text{ horse-power.}$$

Allowing 50 per cent efficiency on working head and 80 per cent on motor, the combined efficiency would be 40 per cent, and the motor horse-power would be 2 divided by 0.4, which equals 5 horse-power.

In Western cities where the water is strongly alkaline it is the practice to install a rain-water storage cistern in the basement, and by means of a water-lift or pump elevate this water into a storage tank in attic, thence supplying the water for lavatories and slop sinks, and for drinking purposes, the flushing of sanitary fixtures and sprinkling of lawns being done with city water.

An excellent example of an installation of this character is in the Federal building at Mitchell, South Dakota. The city water pressure was over 60 pounds, which made a water-lift preferable when relative cost of city water and of electricity was considered. The roof area discharging into storage cistern in basement is 3,600 square feet.

The cistern is 15 feet 0 inch x 18 feet 0 inch inside dimensions, divided into two compartments by means of a 9-inch brick wall with openings at floor of cistern. On the floor of cistern and 12 inches on each side of the division wall, 4½-inch-thick brick walls are erected to a height of 16 inches, and the space between these walls is filled with a layer of charcoal 12 inches deep and covered with a 4-inch bed of sand. The filtered-water compartment from which the water-lift takes suction is 4 feet 5 inches wide and 15 feet 0 inch long. The downspouts discharge into the large compartment.

The cistern was constructed on top of the 5-inch-thick concrete basement floor, and the bottom of cistern was constructed of a layer of water-proofing, 5 inches of concrete, and 1-inch cement mortar finish coat.

The distance from basement floor to top of side walls of cistern is 6 feet 0 inch, and the side walls are 4-inch-thick brick walls plastered with 1-inch cement coating, then a layer of waterproofing, and then a brick wall with a batter on the exterior, thickness at top 24 inches and at bottom 36 inches. The entire cistern is covered with 2-inch x 8-inch wood joists, 1 foot 10 inches on centers, the joists being covered with 1¼-inch tongued and grooved boards. Hinged trap doors 24-inch x 36-inch are placed for access to storage portion and filtered-water space. Minimum space between bottom of first-floor construction and top of cistern is 2 feet 6 inches.

The water-lift has a capacity of 600 gallons of water per hour and is of the reciprocating type, 3-inch power cylinder by 3-inch pump cylinder with a 4-inch stroke, and delivers the water into the attic tank with 60 pounds city pressure. The pump governor is so designed that the admission of city water is regulated by the pressure in the lift discharging pipe to attic tank, and when the pump is stopped the valve closes and pump is not under pressure. The pump has a 1½-inch city water connection and a 1¼-inch discharge to attic tank.

The attic tank is 3 feet 3 inches x 6 feet 6 inches x 2 feet 3 inches deep, constructed of ¼-inch tank steel with 2½-inch x 2½-inch corner angles, and is provided with a drip pan 6 inches larger all around than the tank. The tank rests in the pan on three 6-inch I-beams, and the pan is supported on three 8-inch I-beams. The tank is provided with a $\frac{7}{8}$-inch tongued and grooved cover, and inlet to tank is provided with a ball cock.

Where space permits, the attic storage tanks usually hold about 1,000 gallons, and for the average Federal building the cistern in basement should have a capacity of not less than 10,000 gallons.

The size of the storage cistern is generally based on containing one month's rainfall, assuming the rainfall to be 48 inches per year or 4 inches per month. At this rate each square foot of roof would catch about $2\frac{1}{2}$ gallons of water, and in the example just given the cistern would be 9,000 gallons capacity.

The minimum size of cistern is based on containing one month's storage at rate of 2 inches of rainfall per month.

If the quality of city water is satisfactory, but an attic storage tank is necessary on account of the city pressure being low during the day and increasing sufficiently at night to fill the tank, a 1,000-gallon tank (which will generally be 4 feet 0 inch x 6 feet 0 inch x 4 feet 0 inch deep) is installed, and is provided with a drip pan 6 inches larger all around than the tank. The tank and pan always have an overflow to basement sink.

Tank and pan should be constructed of $\frac{1}{4}$-inch tank steel, and the tank should have one longitudinal and two transverse braces $1\frac{1}{4}$-inch diameter, set 30 inches above bottom of tank.

Hot water is supplied to each shower-bath, lavatory, and sink in a Federal building.

The hot-water branch supply connections to fixtures are the same as the cold-water connections previously described: The hot-water supply pipes to toilet-rooms containing three or a less number of fixtures requiring hot water are $\frac{3}{4}$-inch diameter. When there are more than three and not more than eight fixtures a 1-inch diameter connection is made.

Except in one-story buildings, $\frac{1}{2}$-inch diameter return circulating pipes are taken from each riser near the top and collected into a $\frac{3}{4}$-inch return main in basement. The return main is connected with the storage tank and provided with a check valve.

Where the cost of gas does not exceed 30 cents per 1,000 cubic feet, a storage-type, automatic gas water heater is installed; otherwise a cast-iron coal-burning heater is used.

In estimating on storage tanks and hot-water heaters for Federal buildings twenty gallons in the storage tank is allowed for each shower-bath, ten gallons for each sink, and five gallons for each lavatory. In the average one-story and small two-story buildings this will require about sixty-five gallons water storage, or a tank 18-inch diameter by 5 feet 0 inch long, containing a steam coil made of 15 linear feet of 1¼ inch copper tubing.

The gas water heater to be supplied with the above-described tank must be capable of heating 50° four gallons of water per minute. Under ordinary conditions this would heat 50° 200 gallons of water per hour.

The cast-iron water heater to be supplied with above-described tank has a 12-inch-diameter grate and will heat 48 gallons of water per hour from 40° to 140° F.; and at this rate will require firing every eight hours.

The next size storage tank used in Federal buildings is 24-inch diameter and 7 feet 0 inch long, containing 164 gallons of water and a steam coil with 25 lineal feet of 1½-inch No. 16 copper tubing. This tank will serve two shower-baths, five sinks, and from fifteen to twenty lavatories, and may be used with the gas heater above noted.

The coal water heater for the above-described tank has a 15-inch-diameter grate, and a capacity to heat 96 gallons of water from 40° to 140° F. per hour when fired every eight hours.

The largest buildings have a storage tank 36-inch diameter by 8 feet 0 inch long, containing 424 gallons of water and a steam coil containing 36 lineal feet of 2-inch O.D. No. 16 copper tubing. A gas water heater used with this combination should have a capacity of heating six gallons of water per minute 50° F.; and a cast-iron water heater should have a grate 18-inch diameter, and be rated to heat 220 gallons of water from 40° to 140° F. per hour when fired once in six hours.

In general, the storage capacity should be determined by the foregoing rules; and in the large outfits the cast-iron heater should be designed to heat the amount of water in storage tank in two hours when the boiler is fired once in six hours.

REFRIGERATION AND SANITARY DRINKING FOUNTAINS

In Federal buildings of the largest size it is now the practice to install a complete refrigerated drinking-water system with a motor-driven ammonia compressor. A drinking faucet is provided in each room over the lavatory, and bubbling drinking fountains are placed in the post-office workroom and in the corridors adjacent to court rooms, these being the only points at which a large number of persons are employed or congregate.

In smaller buildings the refrigeration is omitted, but it is the practice to install one or more (depending on size of room and number of employees) of the pedestal-type bubbling fountains in the post-office workroom and one wall-type fountain in corridor adjacent to each court room, the two sets of fountains being connected to separate ice-boxes in basement, as described below.

The workroom fountains are of the pedestal type, and if not more than two (which number is seldom exceeded), are connected to *one* specially-designed ice-box in basement, containing 50 lineal feet of $\frac{3}{4}$-inch block-tin pipe coil. The drinking water passes through the coils, which are in contact with the ice.

The fountains for court-room corridors (one fountain to each court room) are connected to a *separate* box in basement, similar to that above described.

A water pressure regulator is always placed on the water supply to the ice-boxes and set to give a good stream at the highest fountain and nullify the effect of fluctuation in the city water-supply system. A small disc-type filter is sometimes placed on water supply to ice-box.

Each ice-box holds about 300 pounds of ice; and each pedestal fountain will use about 200 pounds of ice per day in a properly-constructed box, and will consume about 200 gallons of water per day.

In the office rooms, which contain but few persons and are not visited by the general public, ordinary water-coolers are placed, and each occupant is furnished with a drinking-glass.

The policy of supplying sanitary fountains for post-office workrooms and court-room corridors is being extended to old buildings as rapidly as conditions in connection with appropriations will permit.

TESTS OF PLUMBING AND DRAINAGE SYSTEM

Special precautions are taken to insure that all parts of the plumbing and drainage system are free from defects and leaks, and the following specification requirements are prescribed with that in view:

The entire system of soil, waste, drain, and vent piping, including the interior downspouts and rain-water drainage system, must be tested with water or air, as hereinafter described, and proved tight to the satisfaction of the superintendent of construction before the immediate connection is made to city sewer, trenches back filled, piping covered, or fixtures connected.

Either the water or the air test may be used, except when there is danger from freezing, when the test must be made with air.

Wooden plugs are not to be used in making the tests.

The connections between the building and the city sewer and the drainage system below the basement floor are to be tested separately.

Water tests. If tests are made with water, the connection from the building to the city sewer and the drainage system below basement floor are each to be filled with water to top of a vertical section of pipe 10 feet high, temporarily connected to the highest point on the lines to be tested, and the water allowed to stand at least 30 minutes for inspection, after which, if the lines prove tight, the water is to be drawn off, immediate connection made with city sewer, and trenches back filled.

The soil, waste, drain, and vent piping, the interior downspouts, and rainwater drainage system above the basement floor line must have the openings plugged where necessary and the piping system above basement floor filled with water to the level of the main roof gutters and allowed to stand at least 30 minutes for inspection, after which, if the lines prove tight, the water is to be drawn off and the fixtures connected. Each vertical stack above basement floor with its branch waste and vent pipes may be tested separately by inserting plugs in the cleanouts at base of verticals in lieu of filling entire system in building with water.

Air tests. If tests are made with air, a pressure of not less than 10 pounds per square inch, equal to 20 inches of mercury, must be applied with a force pump, and said pressure maintained at least 15 minutes without leakage.

A mercury column gauge must be used in making the air tests. Testing instruments must be furnished by the contractor.

Smoke test. After fixtures have been connected, a smoke test must be applied to the sanitary system, and the entire system proved tight, to the satisfaction of the superintendent, when filled with smoke under pressure equal to 1 inch of water. The smoke machine must be provided by the contractor.

Test of water-supply system. At completion of the work, except application of the non-conducting coverings, the water-supply system must be tested to a hydrostatic pressure of 100 pounds to the square inch.

Any water piping run in chases in walls must be tested to above pressure and proved tight before the chases are covered. The test pump must be provided by the contractor.

Cost of tests and certificate. Cost of tests to be borne by the contractor, who must furnish the office, through the superintendent, with a certificate that the required tests have been satisfactorily made.

Certificate must be countersigned by the superintendent, who will forward same to the Supervising Architect.

ESTIMATING DATA FOR PLUMBING AND DRAINAGE SYSTEMS

After the drawings for a plumbing, drainage, and water-supply system are prepared an approximation of cost must be made in order to be able to determine whether the proposals later obtained for the work are reasonable; and the following data, which will generally give results within 5 to 10 per cent of the lowest proposals received, are used:

New building, approximate cost complete plumbing system, including marble finish for all toilet-rooms, average per fixture	$200.00
Old building, approximate cost complete new plumbing system, including marble finish for toilet-rooms, average per fixture	250.00

For estimate on the above basis count as one fixture each:

- Shower-bath.
- Water-closet.
- Slop sink.
- Water heater (with hot-water tank).
- Urinal.
- Lavatory.
- Small sink.
- Interior downspout.
- Fire-hose connection with hose and rack complete.
- Drinking fountain with ice box.
- Four wall hydrants.

Cost of system is divided approximately as follows:

"Roughing in," per fixture	50.00
Marble work, per plumbing fixture	75.00
Fixtures, average each	75.00
Additional for removal of work in place and for cutting and repairs in old buildings, per fixture	50.00

Itemized estimating data. If a very close approximation of the cost of plumbing and drainage system is desired, all pipe, fittings, valves, and fixtures should be taken off the plans and specifications, and the following unit prices used:

Siphon-jet water-closet, 75-pound bowl, with porcelain tank and connections, floor flange, coat hooks, toilet-paper holder, etc., complete in place	$45.00
Siphon-jet urinal with porcelain tank, outlet flange, etc., complete in place	32.00
Vitreous rectangular lavatory, 24-inch x 20-inch, with faucets, nonsiphoning trap, supply and waste connections to wall or floor, compression stops and air chambers on supplies, and with towel rack, complete in place	40.00

Vitreous corner lavatory, without back, including connections and trimmings as described above, complete in place	38.00
Special ice-box, complete in place	50.00
Vitreous corner lavatory, with back, including connections and trimmings as described above, complete in place	40.00
Bubbling fountain, pedestal or wall type, complete in place	40.00
Vitreous slop sink with trimmings, complete in place	75.00
Galvanized-iron sink, complete in place	22.50
Fire-hose rack with 75 feet of 2-inch hose, complete in place	36.50
Roof connections complete in place for down pipes from gutters or for vent stacks:	
2-inch diameter	5.00
3-inch diameter	5.25
4-inch diameter	5.80
5-inch diameter	6.00
6-inch diameter	7.00
Four-inch lead bend with ferrule, complete in place, for basement closet connection	3.00
Three-inch lead bend with ferrule, complete in place for basement slop sink connection	2.75
Cast-iron water heater with 12-inch grate and 18-inch x 60-inch galvanized steel storage tank, with copper or brass steam coil, automatic temperature regulators, and all trimmings, smoke connection, etc., complete in place, including nonconducting covering	180.00
Outfit as described above, without steam coil	160.00
Automatic gas water heater with capacity of four gallons per minute, and steel tank with steam coil as described, complete in place	250.00
Shower-bath fixture with floor drains, soap dish, coat hooks, etc., complete in place	60.00
Anti-freezing wall hydrant, in place	10.00
Excavation for pipe trenches inside of building:	
Trench 3-feet 0 inch deep, per lineal foot	0.15
Trench 4 feet 0 inch deep, per lineal foot	0.25
Excavation for pipe trenches outside of building, trench with average width 3 feet 0 inch and average depth 12 feet 0 inch, in ordinary soil, per lineal foot	1.00
Excavation in rock, per cubic yard	3.00
Repairing streets, allow to cover any kind of work:	
Per square foot	0.30
Per lineal foot of trench	1.00
Street manhole and running-trap manhole, with cast-iron frame and cover, complete in place	75.00
Brick manhole, 18-inch x 30-inch, in basement floor, with cast-iron frame and cover, complete in place	30.00
Area cesspool, complete in place	1.50
Single-hub 3-inch running trap with cleanout plug, complete in place	3.00

Double-hub running trap with cleanout plug and fresh-air inlet, complete in place:

Six-inch	10.00
Eight-inch	18.00

Extra-heavy cast-iron soil pipe and fittings in place, excavation not included:

Diameter *Inches*	Pipe per lineal foot	Bends, ⅛ and ¼	Y's
2	$0.20	$0.35	$0.40
3	0.35	0.55	0.70
4	0.45	0.80	1.00
5	0.50	1.00	1.25
6	0.65	1.50	1.75
8	1.00	2.75	2.75

Standard galvanized wrought-iron pipe and nipples, in place, not including fittings, hangers, or cutting walls, etc.:

Diameter *Inches*	Pipe per lineal foot	Nipples
½	$0.07	$0.12
¾	0.08	0.13
1	0.09	0.19
1¼	0.12	0.20
1½	0.14	0.26
2	0.18	0.33
2½	0.27	0.50
3	0.35	0.75
3½	0.42	1.00
4	0.57	1.20
5	0.62	1.85
6	0.85	2.30
8	1.50	3.40

Galvanized cast-iron recessed drainage fittings, in place:

Diameter *Inches*	Ells	Tees	Y's
1½	$0.50	$0.65	$0.70
2	0.60	0.80	0.85
3	1.10	1.25	1.45
4	1.60	2.00	2.20
5	2.40	3.15	3.00
6	3.25	4.60	4.30
8	5.60	9.00	10.50
10	7.50	12.80	14.50

Standard galvanized cast-iron screwed fittings (not drainage fittings), in place:

Diameter *Inches*	Ells	Tees
½	$0.13	$0.15
¾	0.14	0.16
1	0.20	0.22
1¼	0.23	0.27
1½	0.30	0.34

Diameter *Inches*	Ells	Tees
2	$0.40	$0.45
2½	0.55	0.66
3	0.80	0.95
3½	1.00	1.25
4	1.20	1.50
5	1.75	2.25
6	2.40	3.00
8	5.00	6.25

Standard galvanized cast-iron flange unions, in place:

Diameter:	
2	$0.75
2½	0.95
3	1.15
3½	1.40
4	1.65
5	1.75
6	3.00

Pipe hangers and pipe sleeves in place, including cutting of 18-inch-thick brick walls for sleeves:

Diameter *Inches*	Hangers	Sleeves
½	$0.80	$1.25
¾	0.80	1.25
1	0.80	1.30
1¼	0.80	1.30
1½	0.80	1.40
2	0.90	1.50
2½	0.90	1.50
3	0.90	1.90
3½	1.00	2.25
4	1.00	2.50
5	1.25	2.50
6	1.25	3.25
8	1.50	3.50
10	2.00	3.75
12	2.50	4.00

Standard gate valves in place:

Diameter: *Inches*	
½	$0.40
¾	0.50
1	0.75
1¼	0.95
1½	1.40
2	2.00
2½	3.00
3	3.40
3½	5.30
4	6.00

Nonconducting felt covering for hot and cold water piping, take 80 per cent off the "22-cent" list for cost of covering in place complete.	
Terrazzo floor in place, including concrete bed, per square foot	$0.50
Removing old floors and laying new concrete base and terrazzo floor, per square foot	1.25
Marble floor slabs, 2-inch thick, per square foot in place	1.50
Free standing marble, 1¼ inches thick, per square foot in place	1.25
Marble wainscot, ⅞-inch thick, per square foot in place	1.00
Marble coved floor borders, per lineal foot in place	1.50
Nickel-plated brass standards, bracing, angles, etc., in place for marble work in toilet-rooms:	
For water-closet inclosure	18.00
For water-closet stall in carriers' toilet	4.50
For urinal stall	4.50
For shower-bath inclosure	18.00
Cleaning and painting walls of toilet-rooms three coats lead and oil, per square foot	0.30

Especial attention is called to the fact that the foregoing figures are correct for certain special conditions in *new* Federal buildings, but are not applicable under all conditions. Used with judgment they will give accurate results.

GAS PIPING

The practice of the office is to install a complete gas piping system in every building, both for emergency use and to serve as a check on the cost of electric current supplied by local lighting companies, and while the system costs less than any other portion of the mechanical equipment, it gives more trouble than all the rest of the work. Specifications are carefully drawn, and repeated and strict tests are imposed, and superintendents of construction and inspectors are charged to give special attention to this branch; but with all these precautions trouble frequently ensues.

In making an extension to a building only a few years old it is usual to find the gas piping system in a bad condition and filled with leaks which are difficult to locate and costly to repair.

Gas piping in old buildings is tested to only 3 inches of mercury, which must stand one hour without perceptible drop. This test is made with lighting fixtures disconnected and outlets capped.

With old fixtures and old piping the test is reduced to 2 inches; and with new piping and new fixtures it is made to 3 inches of mercury.

The gas piping system will average $3.50 per outlet in new buildings, and if the total piping is measured up, 15 cents per foot for all sizes will be about correct.

The following is a sample specification such as is used for a new building:

SPECIFICATION

This specification includes the installation of a complete system of gas piping for supplying all the lights (except such as are delineated as "electric only") indicated on the drawings.

The gas meter will not be furnished or set under this contract.

All the gas outlets (except vault outlets and outlets indicated on plans as gas only) to be arranged so as to allow placing on same of electric conduit boxes for combination fixtures.

Contractor to bring into the building a gas supply pipe of size noted on drawings, leaving capped outlet where indicated; and furnish and place at curb line a stop cock or tee-handled gate valve on same, also a cast-iron extension stopcock box, located as directed. Gas main just inside of basement wall to be provided with a brass gas cock.

Kind of pipe used from street main to inside of building and manner of laying same to be in accordance with the regulations of the gas company. If the company will not permit installation of pipe of size noted on drawing, the contractor must take up the matter, before installing the work, with the superintendent, who will refer the matter to the Supervising Architect.

Gas pipes in building to be "standard" gauge galvanized wrought-iron or mild steel, and all fittings to be galvanized, malleable-iron, *beaded* fittings.

Unless otherwise noted or indicated on the drawings the size of gas pipes to be as follows:

Size of pipe *Inches*	Greatest length allowed *Feet*	Greatest number of burners
$\frac{1}{2}$	30	5
$\frac{3}{4}$	50	20
1	70	35
$1\frac{1}{4}$	100	65
$1\frac{1}{2}$	150	100
2	200	200

Main gas pipe of size noted on basement plan to start at point indicated, with capped inlet near basement ceiling, run along same to vent shaft or lookout shaft as shown. From the main, near shaft, a separate riser is to be taken and run up in shaft to supply the horizontal branches in each floor. Each separate riser is to be controlled by a gas cock, located where indicated on plan.

Insert in main where shown near foot of risers a "T" fitting, and a 12-inch piece of pipe of same size as main, with reducing fitting, to be placed for the purpose of collecting drip and scales; a short piece of $\frac{3}{4}$-inch pipe with gas cock to be screwed to reducing fitting, so that drip can be drawn off when necessary.

Plugged outlet of size noted on drawing to be provided on gas main in basement at point indicated, for connection to special furniture fixtures to be placed under another contract.

Gas main to be supported close to basement ceiling with wrought-iron or malleable-iron hangers, and risers, except those of short length, to be securely supported in an approved manner.

Branches from pipes run in first floor to brackets in unplastered rooms in basement, the gas main in basement, the branches from the main in basement for the supply to exterior lamp standards and brackets (except bracket at mailing platform), the branch in basement to post-office screen lights, and all gas pipe in attic or roof space to be run exposed. All other gas pipes to be concealed.

The supply branches to each exterior lighting fixture (except lamp bracket at mailing platform) and to the screen lights to be fitted with gas cocks so that supply to said lights can be controlled. Cocks to be placed where indicated on drawings.

Bracket lights to be supplied by branches taken from the gas piping run in the floor construction of the story in which they are located. Bracket lights in basement to be supplied from main in first-floor construction.

Gas outlets for bracket lights to be set approximately 7 feet above floor, unless otherwise noted. Supply pipe for post-office screen lights to be taken from main near basement ceiling at point indicated, and run up concealed in screens and along same in space provided for pipes, with outlets at points indicated. These outlets will be, in general, about 7 feet above floor.

The gas outlets for all vaults to be taken from gas pipe below floor, and run up in wall alongside of vault doors to a distance of 5 feet above floor line; outlets to extend just beyond finished plaster line, and ends to be capped.

Gas nipples for fixtures to be at right angles to the walls and ceilings from which they project, and to project from finished plaster line of ceiling not less than $\frac{3}{4}$ inch nor more than $1\frac{1}{4}$ inches, and from finished plaster line of walls not less than $\frac{1}{2}$ inch nor more than $\frac{3}{4}$ inch, and be properly fitted and capped. This requirement will be strictly enforced.

No branch pipe from main to be less than $\frac{1}{2}$ inch internal diameter.

Outlets for all brackets, vault outlets, and drops for all chandeliers to be $\frac{1}{2}$-inch diameter.

Drops for chandeliers must be taken from center of a "T" branch; and where a chandelier occurs at the end of a branch, or at end of a run of main, the extra opening in the tee to be fitted with a capped 12-inch length of pipe to form a proper support for the fixture.

All gas pipe to be run regularly and in a workmanlike manner, using all necessary fittings, and in no case springing or bending the pipe to reach a point desired.

All pipes to be run level where possible, and when necessary to be pitched, to grade down toward riser, and to be without traps.

The use of salt water or any other corrosive substance to make piping tight is strictly prohibited.

Each length of pipe must be hammered and all scale blown out before assembling.

Pipe and fittings to be put together with red lead, litharge or any approved compound.

No gas fitters cement will be allowed except at outlet caps.

The entire gas-pipe system inside of building must be tested for one hour with air pressure equal to 15 inches of mercury (1) as soon as laid, (2) before the last coat of plaster is put on, and (3) on completion of the plastering and before lighting fixtures are hung. The mercury during test must not drop more than $\frac{1}{4}$ inch during the hour. Test pump and gauge must be provided by contractor.

Tests to be made by the contractor, at his own expense, and he to furnish the office, through the superintendent, with a certificate that satisfactory tests have been made. The certificate must be countersigned by the superintendent, who will forward same to the Supervising Architect.

CONDUIT AND WIRING SYSTEMS

For electric lighting installations in Federal buildings the standard arrangement is an underground service connection to an entrance switch just inside of the building. In buildings where only two distributing cabinets are used the entrance switch and the sub-feeder switches are concentrated in the same cabinet. In larger buildings, requiring three or four distribution cabinets, there is installed a sub-feeder tablet from which sub-feeder or mains are run to the various distribution cabinets throughout the building. Where more than four distribution cabinets are necessary the sub-feeder cabinet and main switch cabinet are eliminated, if the conditions are favorable, and a switchboard is installed.

In large buildings where an electrical generating plant may be installed at some future time, a standard type of switchboard is placed in the engine room with a service connection to the mains of the local companies.

The main service switch is usually located as near as practicable to the point at which the feeder circuit enters the building, and the sub-feeder tablet or the switchboard is so located as to obtain the best runs and the shortest average length (capacities considered) of sub-feeders. The point sought for is one at which the sum of the products obtained by multiplying the length of each sub-feeder by the number of its ampere capacity is a minimum. The location for main service switch and sub-feeder tablet or switchboard is selected with due consideration to the character of the room, and coal rooms, storage rooms, and letter carriers' lounging and toilet rooms are never chosen.

The distribution cabinets for the post-office section are located in the post-office workroom, so that all the lights in the workroom and in letter carriers' lounging and toilet rooms, and generally in the executive offices of the post office also, can be controlled from same. All other cabinets in the building are located in public spaces (corridors or lobbies) or in the basement outside of post-office space and storerooms.

The locations sought for distribution cabinets are those which will admit of reaching same readily with the feeder, and making all branches of approximately equal length, the maximum length being generally 100 feet. Architectural features of a building are also considered.

The public lobby on first floor and the exterior lights at main entrance are controlled by a cabinet located in the basement, or, in special cases, in the lobby. Where not more than three circuits are required to supply a floor above or below a given cabinet, they are taken therefrom.

As a general rule not more than twelve circuits are taken from a cabinet, and one or more spare switches are provided on each distributing cabinet.

In locating distributing cabinets in thin walls care is taken to see whether a steel beam is located directly over the cabinet; and should this be the case, the structural engineer is requested to substitute two channels for the beam and set the backs of the channels 1½ inches apart.

A cabinet is never located in a partition wall which is less than 4 inches thick exclusive of plaster.

Cabinets containing the distributing panels are of steel, and cabinets and tablets are of special design.

The tablets are of marble and contain 25-ampere switches and 10-ampere enclosed fuses controlling the various circuits.

All wiring is run in rigid metal conduits, and all main service connections to the building are made underground and usually from a steel pole located on the Federal property by the government. If special conditions forbid this, an underground connection is made from the service company's poles adjacent to the building site.

The conduits to service company's poles are run up same 10 feet 0 inch and provided with a weatherproof hood. The practice of the office was formerly to install handhole boxes at the base of service poles, but this has been abandoned as unsatisfactory, except in special cases.

The junction box on main feeder conduit inside of basement is not, as a rule, made less than 6 inches x 6 inches x 4 inches deep.

The feeder and other conduits in basement 1-inch diameter and larger are run exposed on basement ceiling and are installed parallel to the lines of the building. As a general rule all other conduits in the building (except in roof space and in unfinished attics) are concealed.

Conduits in floors are run in the most direct manner and are not usually made larger than 1½-inch diameter, a larger size being difficult to conceal in floor construction.

Care is taken that conduits do not cross each other in the floor construction in such manner as to occupy more than 3 inches total space.

In most cases the conduits run up from the cabinets and run in floor construction above with drops to the single-pole snap switches at entrance doors. This is, however, governed by the contruction, ceiling heights, etc., and an effort is made to reduce the length of the runs to a minimum.

The following tables are used to ascertain the sizes of conduits to accommodate the various sizes and numbers of wire:

CONDUIT SIZES FOR CONDUCTORS

Wire and cable size	Two wires same size	Three wires same size	Four wires same size	Three wires double size neutral	Duplex wires
	inches	*inches*	*inches*	*inches*	*inches*
14	½	¾	¾	¾	½
12	¾	¾	¾	¾	½
10	¾	1	1	1	¾
8	¾	1	1	1	
6	1	1¼	1¼	1¼	
5	1¼	1¼	1¼	1¼	
4	1¼	1¼	1½	1½	
3	1¼	1½	1½	1½	
2	1½	1½	2	2	
1	1½	2	2	2	
0	2	2	2	2½	
00	2	2	2½	2½	
000	2	2½	2½	2½	
0000	2½	2½	2½		
200,000	2½	2½	2½		
250,000	2½	2½	3		
300,000	2½	3	3		

The above table is based on double-braided rubber-insulated wire and unlined metal conduit.

The conduit sizes are given for runs up to 100 feet with not more than four right-angle bends between outlets. For longer runs larger conduits are used.

LEAD ENCASED CABLE IN UNLINED METALLIC CONDUIT

Wire and cable size	Two wires same size	Three wires same size	Four wires same size	Three wires double size netural
	inches	*inches*	*inches*	*inches*
8	1¼	1½	1½	1½
6	1½	2	2	2
5	2	2	2	2
4	2	2	2½	2½
3	2	2	2½	2½
2	2	2½	2½	2½
1	2	2½	3	3
0	2½	2½	3	3
00	2½	3	3	3
000	2½	3	3	3
0000	2½	3	3	
250,000	3	3	3½	
300,000	3	3½	3½	

OUTLETS

The standard type of outlet box suitable for rigid conduits is used. No conduit larger than $\frac{3}{4}$ inch is connected to any outlet box, and not more than four connections are made to any outlet box.

Outlets are located with reference to the architectural treatment and the construction of a building. This generally requires symmetrical spacing.

Ceiling outlets are used for general illumination, and bracket outlets only where space restrictions demand, i.e., small toilet-rooms, stair landings, low ceilings, etc. In addition to ceiling outlets, bracket outlets are always provided in court rooms.

As a general rule, ceiling outlets in the same space supply from 100 to 300 square feet of floor area.

In general, the capacity of a ceiling outlet does not exceed 300 watts; a bracket outlet, 50 watts; a receptacle, 50 watts, Bracket outlets in court rooms, in lobbies, on exterior of building, etc., will supply 100 or more watts. Court-room and lobby ceiling outlets, where the total number of outlets is restricted by the architectural treatment, have a greater capacity than 300 watts, and such outlets sometimes require more than one circuit.

Rooms less than 20 feet square have one ceiling outlet. Rooms over 20 feet in either dimension have two or more ceiling outlets placed on the longer dimensions, the number of rows of outlets being governed by the width of the room.

In the post-office workroom, a space about 3 feet adjacent to the screen is considered to be sufficiently lighted by the brackets on the screen, and this area is deducted from the total area of the room when calculating the illumination.

In locating outlets in large office rooms consideration is given to the possibility of such rooms being subdivided at some future time.

The location of ceiling outlets in court rooms and in main lobbies depends very largely upon the design of the ceilings and other architectural features of these spaces.

Ceiling outlets are located in the centers of square whenever practicable.

It is considered that approximately uniform illumination is obtained when the distance between the outlets is equal to twice the height of the lamps above the plane of illumination, using reflectors which direct the greatest portion of the light downward within an angle of 60° from the vertical and with the maximum apparent candle-power at about 45° from the vertical.

Outlets near beams are located a sufficient distance from the beam to admit of placing a standard 4-inch outlet box, and if the beams projects below the ceiling the outlet is located a minimum of 10 inches from the outer edge of beam flange. If a beam is directly over a necessary or very desirable location for an outlet, an effort is made to have the structural engineers substitute two channels with a 1½-inch space between the same for the single beam.

Outlets are not placed within 6 inches of heating mains or other large piping.

Ceiling outlets are not placed on skylight frames unless this is absolutely necessary, and then the architectural draftsman is called upon to give special construction of the frames to accommodate the conduit and gas piping, outlet boxes, canopies, etc.

Combination ceiling outlets are not used where ceiling heights are less than 8 feet 6 inches.

The standard height of bracket outlets is 7 feet above the floor, but they are frequently placed higher in court rooms.

Bracket outlets are located so that the fixture canopy will seat on a smooth plane surface not less than 5½ inches wide.

Bracket outlets are provided over each window in the post-office screen, unless two windows are quite close together, in which case one outlet will serve both. Bracket outlets are provided on the lock-box section also, on the basis of one outlet for each 4 to 6 feet of length of the box section.

To supply the local illumination of furniture in the post-office workroom, junction boxes with closed covers are set out fully exposed on the basement ceiling. One box is provided for each 300 square feet of floor area, and each box is rated at 500 watts in calculation of wire sizes.

Receptacle outlets for local illumination are placed in walls of all office rooms, and also in floors of the principal offices.

The floor outlets are located on center lines of rooms, longer dimension, and one floor outlet is provided for each 250 square feet of floor area when more than one such outlet is needed.

Desks are generally placed so as to receive a maximum amount of daylight, and this guides the selection of the locations for wall outlets. One such outlet for each two windows of the average office is provided unless conditions indicate the need of a greater number. Money order and registry rooms have one or more wall outlets.

An outlet is provided in each elevator and lift shaft, and located near center of travel of car.

A plug receptacle is provided in the floor under each end of the judge's bench. A plug receptacle is also provided for the clerk's desk.

Bracket outlets are provided over the wall writing desks in public lobby.

Outlets on portable lobby desks are so connected that tearing up of floor to place conduit will not be necessary; a junction box is set on basement ceiling near probable location of riser to desk bracket, and the horizontal run of conduit from box to desk riser is exposed on basement ceiling.

The ceiling outlets in the first-floor lobby are supplied by at least two circuits.

The outlet for the elevator circuit is generally connected on a basement circuit which supplies outlets in boiler room.

The special junction boxes on the basement ceiling are connected two on a circuit; or, in case of an odd number, one or three per circuit.

Branch circuits are connected so that the loads on the two sides of the 3-wire circuit will be approximately balanced.

Outlets in public toilets and in attics are connected on corridor circuits.

Independent circuits are provided for post-office screen outlets.

Lobby outlets, outside entrance outlets, and basement outlets not in spaces connected with post-office working space are connected to a tablet in lobby or basement.

The outlets for lobby desks are connected to either the workroom or lobby tablets.

In court rooms an independent circuit is provided for the outlets at the judge's and clerk's desks, and if conditions require two circuits are provided to each ceiling outlet.

Outside fixtures at each entrance are usually connected on a separate circuit, but where the fixtures are small those at two entrances are connected on one circuit, each entrance being controlled by a snap-switch.

Lead-covered, rubber or paper insulated wire is run from junction boxes just inside wall in basement to outdoor lights at main entrances.

A plug receptacle is provided on exterior of each vault in the building, near lock side of door; and if the vault exceeds 80 square feet in floor area a ceiling outlet box is provided in vault with a receptacle just inside of vault door, so that the inner and outer receptacles may be connected with a flexible cord when desired.

Outlets are located in the roof space or attic, and in basement and machinery spaces, as judgment dictates. Ample illumination is provided for the overhead sheaves of elevators.

Each branch circuit is controlled by a double-pole knife-switch located on the distributing tablet.

Except for the post-office workroom and basement and unfinished attic or roof spaces, all ceiling outlets and all bracket outlets located over 9 feet 0 inch above the floor are controlled by snap-switches. Snap-switches are single-pole flush type, and are set 4 feet 0 inch above the floor; and those in public spaces have lock attachment.

Snap-switches in rooms are located near the entrance door casing on the lock side. Large rooms which have two entrance doors from corridor and more than one ceiling outlet have a snap-switch at each entrance door. Switches controlling large spaces and long corridors are frequently placed in gang boxes, but not more than three switches are placed in one gang box. Switches are not located in partition walls less than 4 inches thick, and are so placed that the face plate will seat on a smooth plane surface.

A uniform size 10-ampere fuse is used for all branch circuits. The smallest wire in lighting fixtures used is No. 16 B. and S. gauge. The sizes of fuses for feeders and sub-feeders are selected to correspond to the carrying capacity of the wires which the fuses protect. In case of a small switch controlling a large cable the size of the fuse is adapted to give protection to the switch.

GENERAL ILLUMINATION

In computing the number of watts required for a certain area the well-known formula recommended by the National Electric Lamp Association is used:

$$\text{Watts} = \frac{\text{Floor area in square feet} \times \text{foot candles}}{\text{Lumens per watt}}.$$

It is convenient to solve directly for the number of lamps for a given area; the above formula then becomes:

$$N = \frac{\text{Area in square feet} \times \text{foot candles}}{\text{Watts per lamp} \times \text{lumens per watt}}.$$

For a 40-watt tungsten lamp installation:

$$N = \frac{A \times I}{K \times 40} = \frac{A \times I}{160}, \text{ where}$$

K = 4.
A = area in square feet.
I = illumination in foot candles.

The required light intensity for general illumination, the planes of illumination, and the allowable number of square feet per 40-watt lamp for the several classes of rooms are as follows:

Space	Foot candles	Plane of illumination (above floor)		Square feet per 40-watt lamp
		feet	*inches*	
Post-office workroom	1.5 to 2.0	3	6	80 to 110
Store rooms, machinery and boiler rooms, corridors, halls, mailing vestibules, and stairs	1.20	3	0	133
Swing room, offices, large toilet-rooms, large vaults	1.5 to 2.0	2	6	80 to 110
Court rooms, jury rooms, money-order and registry rooms, main lobby	2.00	2	6	80
Civil service rooms	3.00	2	6	55
Drafting rooms	5.0 to 6.0	Drawing board		30

The following table gives the lumens per watt for the lamps and reflectors used:

Lamps	Walls	K
Tungsten	Light	4.0
Tungsten	Dark	3.4
Gem	Light	2.0
Carbon 3.1 W.P.C.	Light	1.7
Arc lamps	Large areas	3.0

The value of K used is taken at 4 for tungsten lamps and light walls.

The above values apply to small and medium size rooms. Very large rooms are given special consideration.

WIRING

The standard wiring for lighting in all buildings is 3-wire feeders, 3-wire sub-feeders, and 2-wire branch circuits. This may be varied to suit local conditions, as in a 4-wire distribution system the four wires will be brought to main feeder tablet or switchboard and 3-wire feeders run from this point to distributing cabinets.

The even-number wire sizes are used for feeders, and for sub-feeders smaller than No. 5.

In the smaller buildings the least practicable number of wire sizes for feeders is used.

All branch lighting circuits are No. 12 B. and S., except circuits to the special junction boxes on basement ceiling for furniture lighting, which are made No. 10 B. and S.

The maximum allowance for branch circuits is 660 watts, except for circuits which supply a combination of outlets for both general and local illumination, when a maximum of 800 watts may be installed. In this case, however, not more than three-fourths of the total wattage supplies general illumination.

All lighting feeders and sub-feeders (or mains) are calculated on the following basis:

The assumed lighting load is the total watts for general illumination plus the total watts for local illumination (50 watts per receptacle) plus one watt per square foot of post-office workroom floor space.

Load factors for small buildings, one to one and a half stories.

Feeders	Full connected load
Sub-feeders	Full connected load

Load factors for buildings containing not more than four distributing tablets.

Feeders	70 per cent of connected load
Sub-feeders	80 per cent of connected load

Sub-feeders to workroom and court-room tablets are calculated for full load in all cases.

Voltage drop.

	per cent
Feeders	3
Sub-feeders	2

Feeders and sub-feeders for all buildings containing not more than four distributing tablets are calculated on the basis of 2-wire circuits and 110 volts. The wire size given by formula is the neutral, and each outside wire is one-half the neutral size, so that the systems may be used either for 2-wire or 3-wire service. No feeder or sub-feeder neutral wire is less than No. 8 B. and S. or larger than 300,000 cm.

Where a building contains more than four distributing tablets and the supply system is the usual 110–220 volt 3-wire system, a straight 3-wire system 110-220 volts is used up to the distributing cabinets. The wires are calculated for outside volts, and the neutral wire is made the same size as one of the outside wires. The feeders and sub-feeders are calculated for full-connected load, and with 2 per cent drop in sub-feeders and 3 per cent drop in main feeder.

The three wires of a 3-phase circuit and the four wires of a 2-phase circuit are all made of the same size, and each conductor is of the cross-section given by the formula hereinafter stated.

Branch circuits to single arc lamps are increased 50 per cent to provide for the extra current at starting.

The carrying capacity of all feeders and sub-feeders at the load factors given is not to be less that hereinafter stated, regardless of the voltage drop. This requirement will generally determine the wire size, but in all cases the voltage drop on feeders and sub-feeders is calculated. As a rule, the drop is less than the allowed maximum in sub-feeders 60 feet long and under, and in main feeders 100 feet long and under.

WIRING FORMULAE AND TABLES

$$CM = \frac{D \times W \times K}{P \times E^2};$$

$$\text{Volts lost} = \frac{P \times E \times B}{100};$$

$$\text{Current in main conductors} = \frac{W \times T}{E};$$

where

W = total *actual watts* delivered.
D = distance one way in feet.
P = loss in line in per cent of W; i.e., of power delivered. (P is a whole number.)
E = voltage between main conductors at the lamps or motors.
K = constant from the following table.
B = constant from the following table.
T = constant from the following table.

VALUES OF K

A. C. System	Per cent power factor				
	100	95	90	85	80
Single-phase..........	2,160	2,400	2,660	3,000	3,380
Two-phase (four-wire)...............	1,080	1,200	1,330	1,500	1,690
Three-phase (three-wire)..............	1,080	1,200	1,330	1,500	1,690

K for direct current = 2,160.

The value of K for any particular power factor is:

$$K \text{ for single-phase} = \frac{2160}{(P.F.)^2}.$$

$$K \text{ for 3-wire three-phase and for 4-wire two-phase} = \frac{2160}{2(P.F.)^2}.$$

VALUES OF B

Wire size B. and S.	Power factor per cent							
	25 cycles				40 cycles			
	95	90	85	80	95	90	85	80
0000	1.17	1.16	1.12	1.06	1.32	1.26	1.36	1.32
000	1.12	1.09	1.05	0.99	1.24	1.26	1.24	1.19
00	1.08	1.04	0.99	0.92	1.18	1.18	1.14	1.09
0	1.05	1.00	0.94	0.87	1.13	1.11	1.06	1.01
1	1.02	0.96	0.90	0.83	1.09	1.05	1.00	0.94
2	1.00	0.93	0.86	0.79	1.05	1.01	0.95	0.88
3	0.98	0.91	0.84	0.76	1.02	0.97	0.90	0.83
4	0.96	0.89	0.81	0.74	1.00	0.94	0.86	0.80
5	0.95	0.88	0.80	0.72	0.98	0.92	0.84	0.77
6	0.94	0.86	0.78	0.70	0.97	0.90	0.82	0.74
8	0.93	0.85	0.76	0.68	0.94	0.87	0.79	0.71
10	0.92	0.83	0.75	0.67	0.93	0.85	0.76	0.68

Wire size B. and S.	Power factor per cent							
	60 cycles				125 cycles			
	95	90	85	80	95	90	85	80
0000	1.53	1.64	1.67	1.66	2.21	2.54	2.72	2.76
000	1.41	1.49	1.50	1.47	1.97	2.22	2.34	2.37
00	1.32	1.36	1.35	1.31	1.77	1.96	2.04	2.04
0	1.24	1.26	1.24	1.19	1.61	1.74	1.80	1.79
1	1.18	1.17	1.14	1.08	1.47	1.57	1.59	1.56
2	1.12	1.10	1.06	1.00	1.37	1.42	1.42	1.39
3	1.08	1.05	0.99	0.93	1.27	1.30	1.28	1.24
4	1.05	1.00	0.94	0.87	1.20	1.21	1.18	1.13
5	1.02	0.97	0.90	0.83	1.15	1.13	1.09	1.03
6	1.00	0.94	0.87	0.79	1.10	1.07	1.02	0.96
8	0.97	0.89	0.82	0.74	1.03	0.98	0.92	0.85
10	0.94	0.86	0.79	0.71	0.99	0.92	0.85	0.78

B for direct current = 1.

VALUES OF T

A. C. System.	Per cent power factor				
	100	95	90	85	80
Single-phase	1.00	1.05	1.11	1.17	1.25
Two-phase (four-wire)	0.50	0.53	0.55	0.59	0.62
Three-phase (three-wire)	0.58	0.61	0.64	0.68	0.72

T for direct current = 1.

The value of T depends upon the system and the power factor.

The constants for alternating-current circuits are based on wires spaced 18 inches on centers. The volts loss in conduit work will be somewhat less than that given by the formula.

A more simple formula to be used when calculating direct-current work is as follows:

$$CM = \frac{D \times I \times 21.6}{V}\text{; where}$$

D = distance *one* way in *feet.*
I = line current in amperes.
V = actual volts drop in transmission.

When this formula is applied, it will give the size of conductor for a 2-wire transmission. If the 3-wire system with the double neutral is desired, then this gives the size of the neutral conductor, and each outside is to be made one-half the size of the neutral.

If the Edison 3-wire system (all conductors of the same size) is desired, then the same formula is applied with the following changes:

I = one-half of total current if power is transmitted by the 2-wire system, or
I = the current in either of the outside conductors of the Edison 3-wire system.
V = twice the actual volts drop if the power is transmitted by the 2-wire system.

These different calculations are based upon the same *percentage* loss of voltage in transmitting the power.

In direct-current circuits the volts drop per wire = IR, and the total volts drop = $2IR$. I is the current per wire, and R is the resistance in ohms per wire.

In alternating-current circuits the volts drop depends on both the resistance and reactance. With wires close together as in conduit work the reactance will generally be small. However, for all alternating-current circuits the volts drop should be calculated at the assumed power factor, load, and corresponding current, using the following formula:

Volts drop per wire = Ohmic volts $\times$ cos. ϕ + induction volts $\times$ sin. ϕ.
Cos. ϕ = power factor of the load.
Volts drop, single-phase circuit = 2 (volts drop per wire).
Volts drop, 2-phase circuit = 2 (volts drop per wire).
Volts drop, 3-phase circuit = 1.73 (volts drop per wire.)

In direct-current circuits the volts loss in per cent is the same as the per cent power loss. This is not the case in alternating-current circuits except at unity power factor.

A convenient method of determining wire sizes is to ascertain first the current per wire and select a wire size which has this capacity; then calculate the volts drop for the wire thus selected.

POWER FACTORS—LIGHT AND POWER

	per cent
Incandescent lamps	95
Arc lamps	70
Incandescent lamps and induction motors	85
Induction motors, full load	80
Induction motors, constant speed type, starting	60
Induction motors, elevator type, starting	40

The power factor of an unbalanced 3-phase circuit is obtained from the following formula:

$$\text{Power factor, three phase,} = \frac{\text{Total real watts}}{\text{Volts across lines} \times \text{averages amperes per phase} \times 1.73}$$

WIRE AND CABLE DATA—CONDUIT WORK

Size, B. and S.	Size, circular mils	Safe carrying capacity in amperes	Resistance, ohms per 1,000 feet
14	4,107	12	2.52
12	6,530	17	1.59
10	10,380	24	0.997
8	16,510	33	0.627
6	26,250	46	0.394
5	33,100	54	0.313
4	41,470	65	0.248
3	52,630	76	0.197
2	66,370	90	0.156
1	83,690	107	0.124
0	105,500	127	0.0981
00	133,100	150	0.0778
000	167,800	177	0.0617
0000	211,600	210	0.0489
—	250,000	240	0.0414
—	300,000	270	0.0345

The preceding is used for both interior and underground circuits, and for all kinds of insulation.

Switchboards. In designing switchboards an attempt is made to keep the size of the panels as closely to standards adopted by the various manufacturers as possible.

The majority of switchboard manufacturers make their panels 20 inches, 50 inches, and 70 inches high, and the widths of panels are made 16 inches, 20 inches, 24 inches, 32 inches, and 36 inches. The thicknesses are 1½ inches, 2 inches, and 3 inches.

The specifications usually state that the switchboards shall not be less than 62 inches nor more than 70 inches high and that panels must not be less than 24 inches nor more than 32 inches wide, and the thickness not less than 1½ inches nor more than 2 inches.

ESTIMATING DATA

The average total cost of lighting systems for new buildings, complete in place, can be figured at about $12.00 per outlet in eastern sections of the country, $15.00 in the west and south, and $20.00 in the extreme west.

These figures are based only on the number of actual lighting outlets, switch outlets not being included.

For old buildings the cost of the work will be about $30.00 per outlet in the extreme west, and from $20.00 to $25.00 per outlet in other sections.

Estimating in detail. The total amounts of conduit and wire are the lengths scaled on the plan plus the following:

Number of ceiling outlets x 2 feet.
Number of bracket outlets x 10 feet.
Number of switch outlets x 10 feet.
Number of baseboard outlets x 4 feet.
Number of 2-gang switches x 15 feet.
Number of 3-gang switches x 20 feet.

The average length of branch runs in Federal buildings is 50 feet.

Branch conduits ½ inch; branch circuits in Federal buildings are No. 12 B. and S. duplex wire.

For obtaining lengths of feeders make a diagram of all feeder and sub-feeder circuits.

Materials.

Conduit in place in new building, per 100 feet.

½ inch	$8.50
¾ “	10.25
1 “	13.75
1¼ “	18.25
1½ “	22.00
2 “	30.00
2½ “	47.00
3 “	60.00

Add 50 per cent to above for underground service connections in place and for work in old buildings where walls and ceilings are cut and plaster must be replaced.

Conduit elbows in place, each:

2 inch	$1.00
2½ “	1.25
3 “	4.00
4 “	10.00

Outlet boxes in place, all kinds, each:	
In new buildings	$0.25
In old buildings where plaster must be repaired	0.50
Large junction boxes, per pound, in place	0.05
Plug receptacles in place, each	1.30
Snap switches (single-pole 10-ampere), in place, each	1.00
Fixture studs, each, in place	0.05
Double braided rubber-insulated wire, per 1,000 feet:	
Solid single conductor:	
Size, B. & S:	
16	15.00
14	18.60
12	21.70
10	25.85
Size, C.M.:	
250,000	275.00
300,000	327.00
400,000	405.00
500,000	500.00
Stranded single conductor:	
8	35.40
6	48.25
4	62.65
3	75.25
2	82.00
1	101.30
0	128.00
00	156.00
000	184.25
0000	217.00
Duplex conductors:	
14	30.00
12	34.00
10	40.25
8	49.25
Telephone cabinets, special office design, in place, each	20.00
Outlet bushings, each, in place	0.05
Lock nuts, each, in place	0.01
(Estimate three bushings and three lock nuts per outlet.)	
Reinforced silk-covered lamp cord, No. 16, per 1,000 feet, in place	55.00

Knife switches, 250-volt, single-break, with extension for fuses unmounted, polished:

Capacity	Double-pole	Triple-pole
10	$1.80	$2.30
25	3.05	4.35
100	4.65	6.75
200	7.45	10.95
300	10.45	15.20
400	13.00	19.55
500	18.10	27.00

Capacity	Double-pole	Triple-pole
600	23.10	34.45
800	27.95	41.80
1000	53.35	63.65
1200	67.25	87.40

Cost of mounting, not including drilling of marble, per switch...	$1.00
Enclosed fuses in place, each:	
5 to 65 amperes	0.10
65 to 100 amperes	0.25
110 to 200 amperes	0.50
225 to 400 amperes	0.90
450 to 600 amperes	1.30
Bus-bars for switchboards, per pound, in place	0.50
Structural steel work for switchboards, per pound, in place	0.10
Blue Vermont marble, 2-inch thick, per square foot	2.00
Slate panels, 1¼-inch thick, per square foot	0.50
Drilling holes, slate and marble, each	0.25
Labor on switchboard panels, each:	
In shop	25.00
At building	12.00
Total	37.00
Tablets and cabinets (office special design), per switch	5.00
To actual cost of tablets, if ascertainable, add for installation, per circuit	1.00
Motor connections, 5-H.P. and under, per H.P.	2.00
Motor connections, from 10-H.P. up, per H.P.	1.00
Railroad fare on average Federal building	50.00
Board per man, per day	1.00

Freight, 3 per cent of total cost of material and labor.
Superintendence, 1 per cent of total cost of materials and labor.
Profit, 20 per cent of total cost of materials and labor.

Especial attention is called to the fact that the foregoing figures are correct for certain special conditions in *new* Federal buildings, but are not applicable under all conditions. Used with judgment they give accurate results.

CONDUIT SYSTEMS FOR TIME CLOCKS AND OTHER SPECIAL PURPOSES

The present practice of the office in regard to standard clock systems is to locate a few synchronized clocks in conspicuous positions in the building. One clock, located in the upper part of the post-office workroom, is provided with two faces, one of which is visible from the public lobby and the other from the workroom. For buildings over one story in height, one clock outlet is located in the corridor of each of the upper floors and in the court room. The outlets are interconnected, but not on a closed circuit. Wall outlet boxes are provided for each clock except in the post-office screen, where conduits are terminated with bushings in the space arranged in screen for the reception of the clock.

The clocks are intended to be operated by primary works which are to be synchronized with the standard time signals sent daily over the telegraph lines of the country.

The standard time clock systems formerly installed in Federal buildings under control of the Treasury Department, consisted of a master clock operating by means of electricity or air pressure, with secondary clocks located throughout the building. The secondary clocks contained no driving mechanism proper, being driven solely by impulses from the master clock, and did not require winding, oiling, or setting.

The master clocks for the pneumatic systems were either self-contained or used a water-operated compressor which automatically maintained a constant pressure in a storage tank. The master clock operated a valve once each minute, thus forcing air to travel through the piping and operate the secondaries.

In the electric systems, the secondary clocks were provided with electro-magnets connected in series. The master clock was provided with a circuit-closer which automatically closed the circuit (or relay) once each minute. The magnets in the secondaries were thus energized, and the armature which was attracted moved the hands forward one minute.

The secondary clock circuits for the electric system, if not more than three, were supplied through relays located in the master clock. Each circuit was fitted with a small telltale clock mounted in the master clock.

Buildings with twenty or more office rooms (including post-office workroom, money-order room, and lobby) were provided with a complete conduit system for clocks.

Not more than twenty-five secondary clocks were installed on one circuit, and the circuit began and ended at the master clock. In buildings where there were more than twenty-five secondaries they were grouped on different closed circuits, with not more than twenty clocks on a circuit. The various circuits contained, where practicable, the same number of clocks, and each circuit was connected with the master clock outlet, which was connected to the junction box in the vault protection service conduit just inside of basement wall to permit connections at this point to the battery, or to the lines of the telegraph companies for synchronizing the clocks.

All conduit systems were $\frac{3}{4}$-inch diameter, and the clock outlet boxes were of special design. The conduits were arranged for the pulling in of wires, or of lead tubes for the pneumatic system.

The master clocks were of the wall type and were located in the post-office workroom in such position as to be visible from all parts of the room, care being taken that near-by columns, suspended lookouts, etc., did not obstruct the view. Master clock cases varied in size from 64 inches to 90 inches in height and from 20 inches to 24 inches in width.

A secondary clock was located in each office room throughout the building, in the carriers' swing room, the money-order and registery division, and the court room.

The clocks in office rooms were installed over doors if ceiling heights permitted. In rooms which were long in proportion to their width, the clocks were located on an end wall in preference to a side wall. In extremely long rooms a clock was placed at each end of the room. Clocks in court rooms were placed so as to be easily seen from the judge's desk.

The weight of the average size electric and pneumatic secondary clock used was 4 pounds. For ordinary office rooms where the distance from the clock to any point in the room did not exceed 40 feet 0 inch, clocks with 12-inch-diameter dials were installed. Where the distance was greater, 2 inches were added to the diameter of the dial for each additional 10 feet 0 inch. The standard secondary clock with 12-inch dial was 17 inches x 17 inches outside dimensions.

In court rooms and rooms over 14 feet 0 inch high, the size of the clock dial was determined as above when the clock was to be set 10 feet above the floor. For greater heights above floor, the diameter of the dial was increased approximately 12 inches for each additional 10 feet 0 inch. The architectural treatment of the walls received consideration in deciding upon the size of the clock dial.

The clocks usually had a 12-inch dial, Arabic numerals, and an oak case.

TOWER CLOCKS

Three types of tower clocks are in use on Federal buildings; mechanical, electrical, and pneumatic.

The mechanical tower clocks used have generally the ordinary clock mechanism operated by weights, wound up by hand once a week. This is the cheapest form of clock, and is reliable. The present practice is to require that the mechanical clock weights be automatically wound by means of a motor operated on the lighting circuit or by storage batteries. All clocks are provided with a pilot clock so that the hands may be set from the clock room, and the pilot clock is provided with a second-hand. In order to equalize the cost of the mechanical clock with the other two systems, a clock is placed in some part of the building and operated electrically as a secondary from the tower clock.

All types of tower clocks used are provided with a device for automatically switching on and off the lighting system installed for illuminating the clock dial or dials; and all are guaranteed to vary not more than thirty seconds per month.

The pneumatic system consists of a hydraulic air compressor and galvanized steel air storage tank, with a master clock located in some part of the building, from which the tower clock is operated as a secondary.

If a building is equipped with an electric clock system the tower clock is operated as a secondary from the master clock, the same as any other secondary.

If a building has no clock system, a master clock is installed in the post-office workroom or custodian's office, and the tower clock is operated therefrom as a secondary. The hands of the electric tower clock are operated by a small motor controlled by the master clock, and this motor is wound for 20 to 25 volts and operated by 40 wet cells, which will run the motor one year.

The tower clock mechanism occupies a space about 24 inches x 24 inches in plan, and for the electric system the minimum distance from the center of the clock dial to the stand for supporting the mechanism is not less than 24 inches. The electric clock mechanism weighs about fifty pounds, and is, when possible, located in a room protected from the weather; otherwise it is installed in a glass case.

In the event a bell and striking mechanism is desired in connection with a tower clock, it is located in a room above or below the clock mechanism, or in same room if necessary. The striking mechanism weighs about forty pounds.

The room for the bell has large openings extending from floor to ceiling to permit the egress of sound. If louvres are used they are widely spaced and backed up with wire grills.

A bell room 6 feet 0 inch x 6 feet 0 inch in plan and 7 feet 0 inch to 8 feet 0 inch high is the standard size. The bell room is made not less than 10 feet 0 inch higher than the roof of the building.

The floor and ceiling of the bell room have mineral wool deadening between joists if wood construction is used.

The space occupied by the bell and its supporting stand is approximately 6 feet 0 inch x 6 feet 0 inch in plan for a 2,000-pound bell. On account of hills, street noises, etc., no definite rule can be laid down as to how far a bell can be heard, but under ordinary conditions a 1,400-pound bell can be heard one mile, and a 2,000-pound bell two miles.

In small Federal buildings a 1,400-pound bell is installed, and in the larger buildings a 2,000-pound bell. Chimes or peals are not used.

The clock dials are made 3 feet 0 inch diameter for towers up to 30 feet 0 inch high. For each additional 10 feet 0 inch one foot is added to the diameter of the dial.

The tower clock hands are made of aluminum.

If a bell is installed with a tower clock, and no other secondary clocks are used in the building, the dry batteries for the clock motor can not be used, as the striking mechanism takes too much current; therefore a storage battery is installed, which is charged from the lighting or power service of the building. If only alternating current is available, a rectifier is used and a charging tablet installed, on which is mounted a double-throw switch, voltmeter, ammeter, reverse current relay, and a bank of resistance lamps for charging the storage batteries, consisting of 15 cells each, rated at 4 amperes for eight hours.

The proper illumination of tower clock dials is difficult to arrive at, and generally expensive to maintain. The office has abandoned its former practice of placing a ring of lights about 2 feet back of each clock face and using 40-watt tantalum lamps, as a dark spot will appear on the dial if one light goes out, and the dial will have a spotted effect even with all lights burning. It is better to drop down from the center of the ceiling of clock room with a conduit and place a ring made up of conduit and condulets, or regular boxes with receptacles, to form a large cluster, and install 40-watt or larger tantalum lamps, wired on two circuits. An abundance of light is necessary, approximately 6 candle-feet on the dial being required.

The walls and ceiling of the clock room are given three coats of lead and oil or white enamel paint to increase the reflection.

The best way to illuminate clock dials is to treat the walls of clock room as noted above and drop two arc lamps in center of room, same to be on separate circuits and each large enough for excellent illumination of dial. Two 500-candlepower arcs would be sufficient under ordinary conditions, but each case should be separately figured out.

ESTIMATES OF COST OF STANDARD TIME CLOCK SYSTEMS

Cost per cell (new)	$1.50 to $2.00
Voltage per cell	0.6 to 0.7 volts
Life of cell, approximately	300 ampere hours
Length of contact made by master clock	⅓ second
Voltage required per secondary clock, approximately	1¼ volts
Amperes required per circuit	1 ampere

The number of cells required for operating electric secondaries is equal to twice the largest number of clocks on any one circuit.

For preliminary estimates it is sufficiently accurate to allow about $25.00 per secondary clock and add $200.00 for the master clock. Of the $25.00 per clock, $15.00 may be taken for the clock and wiring and $10.00 for the conduit system. This will give about the lowest cost, and the estimate should be increased from 10 to 20 per cent in remote cities.

One thousand feet of ½-inch conduit in place costs approximately $100.00 in new buildings, and $200.00 in old buildings where cutting is needed and plaster must be patched. One thousand feet of No. 16 wire in place costs approximately $16.00.

The outlet boxes now used in Federal buildings cost about 25 cents each in place in new buildings, and 50 cents in old buildings.

The cost of hanging and connecting an electric secondary clock is about $1.50. Connections are made into top of clocks.

The cost of an average electric tower clock with no other secondaries, including dial, hands, mechanism, batteries, master clock, etc., complete, may be taken at about $1,250.00. This does not include cutting for clock dials, or other structural work.

The mechanically operated tower clocks will average about $1,000.00.

For striking mechanism, including 2,000-pound bell, add $1,100.00. Bells will average 35 to 40 cents per pound at factory.

FIRE ALARM AND WATCHMAN'S TIME-DETECTOR SYSTEM

In buildings with fifty or more office rooms, a conduit system for fire-alarm apparatus and a conduit system for watchman's time-detector are installed.

For the fire-alarm system two outlet boxes, one above the other, are provided at each station; the lower being about 40 inches above the floor and the upper one 6 feet 0 inch above the floor. These boxes are located at various appropriate points in the corridors and elsewhere, and are joined in series by 1-inch conduit. The conduit system begins and ends at a large junction box in the engine room. From this junction box a conduit is run to the place where the batteries are to be located. For convenience, the boxes on the several floors are located in vertical rows, and a single riser is run through all the boxes in that vertical row. These risers are cross-connected in the attic and the basement.

The upper outlet used on the fire-alarm system is similar to the regular switch outlet box, or the regular ceiling outlet box with brass cover with a bushed opening for connection to a small gong. The lower box is 5 inches wide by 8 inches high by 5 inches deep, clear inside, made of cast-iron with a bronze cover flush with plaster line and secured to the box with tap screws. This cover has a hinged door with a plate-glass panel set in same, and the door is provided with a simple catch and knob so that it can be readily opened.

Outlet boxes for the watchman's time-detector system are located in remote corners of the public portions of the building, preferably in vertical rows, and connected by 1-inch conduit similar to the fire-alarm boxes. These risers are run to a common junction box located in the office of the assistant custodian, and from said box a 1-inch conduit is run to the place where batteries are located.

Watchman's clock and fire-alarm systems use No. 16 and No. 18 wire. There is one more wire in the conduit than there are stations on the line. The watchman's boxes are 5 inches wide by 5 inches high by 5 inches deep, clear inside, and made of cast-iron with a bronze cover set flush with plaster line and secured with tap screws.

The cost of these systems will average $10.00 per outlet.

VAULT-PROTECTION SYSTEM

All Federal buildings are provided with a conduit system for the reception of the wires of an electric vault-protection system.

The wiring for each vault consists of a cable which leads to a common junction box for all vaults, which is located in the basement. From this junction box a conduit, never less than 1½-inch diameter, is run underground to the service pole and up inside of same to the top. A ¾-inch conduit is also taken from this junction box and run to a selected point near ceiling of the post-office workroom.

From the junction box in basement a ¾-inch-diameter conduit is run to each vault in the building with a steel outlet box located near door trim on the exterior of the vault about 4 feet 6 inches above the floor, and a box is located near the ceiling on the inside of the vault near entrance door.

The size of the main service conduit from the junction box to the pole is such that the 4-pair cables from each vault when grouped and formed into a cable will not fill more than two-thirds of the conduit.

In the smaller buildings the main service vault-protection conduit is used to bring in the main telephone wires also, and in the larger buildings the vault-protection main service conduit is used to bring in the telegraph wires for the Weather Bureau service and also the clock and messenger call-bell wires from the telegraph companies.

The entire cost of this system will average $10.00 per outlet. The wiring in the conduits is supplied by the companies furnishing the service.

TELEPHONE AND CALL-BELL CONDUITS

A conduit system for telephones and call bells is installed in all Federal buildings, and is so arranged that intercommunicating telephone systems may be installed if desired.

As previously stated, in the small buildings the main service conduit for the vault-protection service is used to bring in the main telephone wires to the junction box in basement. From this junction box in small buildings a conduit is run to a telephone junction cabinet centrally located on first floor; and from the junction cabinet (of special design) radiate separate ½-inch-diameter conduits to the various office rooms and stations.

In the large buildings, if there is only one telephone company in the city, a main service conduit never less than 1½-inch diameter is run from the building underground to the service pole and up inside of same to the top. Just inside of basement wall a pull box is placed, and from this box one or more conduits of suitable size are run and connected to telephone junction cabinets set in corridors, generally just above the baseboard, from which cabinets radiate separate ½-inch-diameter conduits to each office room. In office rooms a floor outlet and a wall outlet are provided for telephone, the wall outlet being located just above the baseboard.

In the large buildings there are generally two junction cabinets on each floor fed by separate risers, generally of the same diameter as the main conduit, and on each floor these cabinets are cross-connected with the same size of conduits.

Where there are two telephone companies in a city, two separate main service connections as above described are installed with separate main connections to the various junction cabinets. The branch connections from the junction cabinets, which are common to both systems, are run in the same ½-inch conduits to the various rooms.

In some buildings separate junction cabinets are supplied for each telephone system with a cross-connection between, so that the ½-inch individual circuits may be used in common.

The call-bell system wires are sometimes run in the same conduits as the telephone wires.

A special call-bell system is installed for the post-office section of the building with outlets located as follows:

	Wall	Floor
Near mailing platform	1	..
Screen near general delivery window	1	..
Center of post-office workroom	1 or more	..
Money-order and registry room	1	
Carriers' swing room	1	..
Boiler room	1	..
Postmaster's room	1	1
Assistant postmaster's room	1	1

The above outlets are connected to the telephone junction cabinet on first floor, and from this cabinet a $\frac{1}{2}$-inch conduit is run to basement with an outlet box near the point selected for the batteries.

The call-bell outlets in screen are set about 4 feet 6 inches above the floor, and outlets in unfinished portions of the basement are placed near the ceiling.

The standard size of telephone junction cabinet is 24 inches wide by 18 inches high and 3 inches deep, and it is constructed of sheet steel with a bronze frame and hinged door with lock and key.

The outlet boxes for telephones are steel, and are provided with a cover of brass for bushed hole in same.

The cost of the telephone conduit systems will average about $10.00 per outlet.

WEATHER BUREAU SPECIAL CONDUITS

In all buildings in which offices are assigned to the Weather Bureau, a large-size floor outlet box with brass cover is placed in the main office room of the Bureau, and a similar outlet box of waterproof type is located on the instrument platform on the roof of the building, these two boxes being connected by a 2-inch conduit for the reception of the instrument wires. The special outlet boxes are generally 6 inches square and 4 inches deep, and the floor box in office room has an opening tapped in same for a $1\frac{1}{2}$-inch conduit connection.

In addition to the above, a conduit is run from the nearest cabinet and tablet of the lighting system of the building and is extended to the instrument platform on the roof and provided with a weatherproof outlet box at that point. One lighting circuit is installed in this conduit.

In buildings located on navigable waters, and which are provided with quarters for the Weather Bureau, in addition to the above conduits a conduit is run from the nearest lighting cabinet and tablet to a weatherproof box on instrument platform. This conduit contains two lighting circuits which are controlled by snap-switches in the Weather Bureau office.

In all cases a 1½-inch conduit is taken from the vault-protection junction box previously noted and run to a floor outlet box in main Weather Bureau office for the reception of telegraph wires and messenger call-bell wires.

CONDUIT FOR SIGNAL SYSTEMS

In all buildings containing a court room, a conduit system is installed for the reception of wires for call-bells, intercommunicating telephones, etc., between various portions of the building.

The system consists of two 1-inch conduits, running parallel, and interconnecting floor boxes of special design located at various points throughout the building. From these floor boxes a ¾-inch conduit is run to a wall box just above the baseboard and another to a wall box just above the picture molding. If there is an adjoining office it is provided with similar outlets opposite and connected to the outlets above mentioned. One set of outlets is placed in each office and in the workroom, money-order and registry room, and swing room; and a floor outlet is located in judge's platform in court room. The entire system is connected with the vault protection system by two 1-inch conduit.

LIGHTING FIXTURES

The present practice of the office is to include lighting fixtures in the general contract for the erection and completion of a building unless the cost of the mechanical equipment and lighting fixtures approximates $25,000, in which event the lighting fixtures are either awarded as a separate contract or embraced in the contract for the mechanical equipment.

For the smaller buildings the requirements for lighting fixtures are standard, and the fixtures are delineated on two standard-size office drawings, each fixture being given an identifying number.

For lighting fixtures for the larger buildings it is the purpose of the office to get out three sets of standard designs; (a) for Classic buildings, (b) for Italian Renaissance, and (c) for Colonial buildings.

The largest and most important buildings will have lighting fixtures of special design; and the architects of "Tarsney Act" buildings will be given an opportunity to design also the lighting fixtures, under the direction of the office.

BASIC DATA IN CONNECTION WITH DESIGN AND INSTALLATION OF LIGHTING FIXTURES

As hereinbefore stated all Federal buildings are wired for electricity and piped for gas, but in towns where there is no gas company the lighting fixtures are designed for electricity only. If a gas plant exists or is contemplated, the lighting fixtures are made combination, so that either gas or electricity may be used. This complicates the design and increases the expense, but until a building is completed and ready for occupany it is difficult to determine which lighting medium will be used, as the competition between the rival companies is usually keen, and the practice of the office in being prepared to use either gas or electricity makes for increased competition and results advantageously to the Government.

Referring to the section of this book entitled "Conduit and Wiring," it will be noticed that certain outlets are made "electric only" or "gas only." Buildings having "electric only" fixtures will generally have "gas only" outlets capped with an ornamental cover called design No. 67.

When conditions require the installation of combination fixtures, inverted gas-mantle burners (Welsbach No. 6) are installed on fixtures in all office rooms, and upright burners (Welsbach Junior) on fixtures in public corridors (except such small corridors as lead to store rooms or unimportant office rooms) for all floors.

The inverted mantle-burner arms and the electric arms are alternately arranged on the body of fixtures No. 500, No. 501, and No. 502.

The No. 510 bracket, when used on the post-office workroom screen, is equipped with a small inverted gas-mantle burner Welsbach Reflex No. 4. In other locations it is equipped with an upright "Junior" burner.

Fixtures No. 511, No. 513, No. 515, and No. 518, used in corridors, are equipped with upright "Junior" burners.

In court rooms pendant fixtures are made for "electric only" service, and are hung with bottom of glassware about 15 feet 6 inches from floor in rooms with 20 foot ceiling. The usual length of fixtures is 4 feet 6 inches for ceilings more than 20 feet high. For ceiling heights less than 20 feet, fixtures No. 514, No. 519, and No. 520 are used in order to obtain proper fixture height. In some cases pendants are dispensed with and special cove or ceiling lights are installed.

Portable desk lamps No. 522 are now used on the judge's desk in lieu of the standards formerly used.

When combination fixtures are used, gas brackets are always installed in court rooms, and are usually provided with plain open-flame gas burners. Combination brackets are used when conditions demand that the ceiling light be supplemented.

For the ordinary building, if the lobby desks are simple in design and are arranged to receive a lighting fixture, they are equipped with No. 505 standards. If the desk design is elaborate, the No. 521 standard is used.

Cord drops are used in boiler, storage, and machinery rooms. In basement they are fitted with porcelain shell sockets; all other sockets have metal husks. Metal reflectors are seldom used on cord drops in basement.

In the post-office workrooms special furniture lighting is installed as illustrated on drawings M.F. 75-A and M.F. 75-B, which are for electric and gas lighting respectively.

Pendant switches are used for all pendants in the post-office workroom and for pendants in office rooms where several fixtures are controlled by one wall switch.

Open-flame gas burners on fixtures are never placed closer than 18 inches to a ceiling; and 15 inches is the minimum distance for upright gas mantles.

The height for pendants in office rooms will vary from 8 feet 6 inches to about 10 feet, depending upon the size of room and the style of fixture used; the minimum height being 7 feet. In post-office workrooms and other rooms where more than one outlet is needed the fixture height above the plane of illumination is one-half the distance between outlets. The minimum height where mail bags are handled is 8 feet 6 inches.

The architectural features are considered in selecting the design of the lighting fixtures for the first-floor lobby, and their height will vary generally from 10 feet to 16 feet, depending upon the area illuminated and distance between the outlets. In lobbies having less than a 13-foot ceiling, a ceiling-light globe fixture is used.

In second and third-floor corridors the usual height for fixtures is 8 feet 6 inches; in case of a low ceiling they may be hung 7 feet 6 inches above the floor, but no lower.

If a basement is less than 9 feet in height, separate gas brackets are used with "electric only" ceiling outlets provided with drop cords; or a ceiling fixture is used if the room is finished.

Mailing vestibules with ceiling less than 10 feet require an "electric only" ceiling outlet and a separate gas bracket.

Bracket outlets are installed 7 feet above the floor as a general rule.

The glassware used in connection with the lighting fixtures is divided into the following types for convenience in preparing schedules:

"A" is the concentrating type, and is used on the brackets on post-office workroom screen.

"B" is the extensive type, and is used on all pendants with 40-watt tungsten lamps.

"C" is the extensive type, and is used on pendants with 60-watt tungsten lamps.

"D" is the diffusing type, and is a plain sand-blasted globe 7 inches diameter.

"E" is the same as "D," except that the diameter varies from 8 inches to 16 inches and the glass is cut in accordance with design No. 63.

"F" is for gas-mantle burners. The pendants with inverted mantles have glassware giving a type "B" distribution curve, while the inverted mantle burners on bracket lights have glassware giving a type "A" distribution curve. For upright burners the glassware is of the diffusing type.

The design of the conduit and wiring system and of the fixtures is based on using the lamps hereafter noted:

Twenty-five watt tungsten for post-office screen, small toilets, and other spaces where less than 30 c.p. is required.

Sixty-watt tungsten for post-office workroom and office rooms requiring more than 30 c.p. More than one 25-watt lamp should not be used at a single outlet.

For lobbies and court room use either the 100, 150, or 250 watt lamp, but use only one of these sizes in a given building.

If a post-office workroom is of such size and shape that a 60-watt layout is not economical, the 40-watt tungsten lamps in the workroom, in connection with the 40-watt "Gems" for the basement, may be used (as heretofore), in which case the 60-watt and 25-watt lamps should not be used in the building.

The height of lamps for pendant fixtures above the plane of illumination should be one-half the average distance between outlets. The plane of illumination in the post-office workroom is considered 3 feet 6 inches above the floor.

For court-room work when ceiling lights are used, the size of lamps should be the same as that used for general lighting in the building, and should be bowl-frosted, pear-shaped tungsten lamps.

The 40-watt "Gem" lamp is used in the unfinished portion of the basement, in store rooms, and where the fixture is subjected to excessive vibration.

Finish of fixtures. Light oxidized brass finish is generally used for all fixtures installed in public lobbies, corridors, court rooms, and important office rooms, and oxidized copper is used in all other parts of the building and for mailing platform bracket. Brush brass finish is not used.

In the larger and more important buildings special finishes are used to harmonize with the architectural treatment.

ESTIMATING THE COST OF LIGHTING FIXTURES

For preliminary estimating it is safe to say generally that the lighting fixtures will cost about the same as the conduit and wiring system.

In Federal buildings a reasonably close approximation of the cost of the fixtures may be made by counting the number of fixture outlets and multiplying by $15.00 for combination fixtures with Welsbach mantles, by $14.00 for fixtures with plain gas burners, and by $13.50 for electric-only fixtures. If there is a court room the cost of fixtures for same should be determined separately, from figures hereinafter given, and be added to the above.

The cost of installing fixtures will average for the entire country 10 per cent of the value of the fixtures, though in the South and West 20 per cent will be nearer the figure.

Special lighting on post-office workroom furniture costs approximately $10.00 per light.

The following tables give closely the average cost of fixtures now used by the office, to which must be added from 10 to 20 per cent for installation:

"ELECTRIC ONLY" FIXTURES

Fixture number	Cost of fixture	Glassware
504	$ 1.90	Metal reflector
506	35.00	E 14-inch
512	23.00	E 12-inch
528	40.00	E 14-inch
529	31.00	E 12-inch
507	8.75	
517	8.50	E 12-inch
508	4.50	B
514	12.50	E 12-inch
519	23.00	E 12-inch
525, seven lights	100.00	Six 8-inch globes One 15-inch globe

"Gas Only," Upright Mantle Burners

Number 511, one-light, with glassware	$9.50
Number 511, two-light, with glassware	14.00

COMBINATION FIXTURES, ETC.

Fixture Number	Arms	Electric only	Combination plain gas	Combination upright gas-mantle burner	Combination inverted gas-mantle burner	Plain gas only
505	1	$12.50		$18.00		
516	1	8.00	$8.50			
516	2	9.00	12.50			
500	2	14.50	15.00		$26.00	
500	3	21.00	23.50		32.00	
500	4	23.00	27.00			
501	1				12.00	
501	2	10.00	11.50		18.00	
501	3	12.00	14.00		24.00	
501	4	15.00	18.00			
501	6	19.00	21.50			
502	1				10.50	
502	2	9.00	9.50		15.00	
502	3	11.00	13.00		20.00	
502	4	13.50	15.00			
502	6	18.00	19.00			
503	1	5.00	6.00			
503	2	6.00	7.50			
510	1	3.00	4.00	4.75	5.50	$2.00
510	2	5.50	6.00	8.25		2.50
511	1	7.50	9.00	11.00		8.00
511	2	13.00	15.00	16.50		10.50
513	1	8.00	10.00			
513	2/1			12.00		
518	1	B 7.00	7.50			
518	2/1			8.50		
518	1	E 10-inch 9.50	10.00	10.25		
526	6	60.00	75.00			
526	6/6			80.00		
527	6	70.00	75.00	80.00		

The following is a typical lighting fixture specification prepared by the office:

SPECIFICATION

Type. All fixtures are to be of the combination type, except where otherwise designated in the fixture schedule. When fixtures shown on the drawings as combination type are specified in the schedule to be "electric only" or "gas only," the fixtures are to be built to correspond to the type specified.

Combination fixtures. The construction of this type of fixtures is to be as shown on drawings, using plain tip burners. Mantle burners to be used when so indicated by symbol in schedule, and to have fixture construction to correspond thereto.

The symbol "U" indicates that the pillars and gas tips are to be omitted and upright mantle burners complete with glassware, as hereinafter specificed, installed in lieu thereof.

The symbol "I" indicates that the regular gas burner attachments are to be omitted and the fixtures constructed with alternate gas and electric arms, the gas arms to be equipped with inverted mantle burners complete with glassware. The glassware on any fixture with inverted mantle burner is to harmonize as to shape and design with the electric glassware specified, and must give the same general distribution of light as the electric glassware. The gas and electric arms are to be as nearly as possible alike in appearance, and the gas arms are to have regular gas cocks in addition to the by-pass cocks hereinafter specified. The bottom of all glassware on the same fixture must be in the same horizontal plane.

"**Electric only**" **fixtures.** The construction of this type of fixture is to be the same as that of the combination fixture, with the omission of all gas burners and of all exposed attachments for same. The piping may be used as a passageway for the wiring.

"**Gas only**" **fixtures.** The construction of this type of fixture is to be the same as that of the combination fixture, with the omission of all electric parts, except that insulating joints for the stems are to be provided:

TYPICAL SCHEDULE OF FIXTURES

Abbreviations in Schedule: O.C., oxidized copper finish; L.O.B., light oxidized brass finish; U, upright mantle burner; I.6, inverted No. 6 burner; I.4, inverted No. 4 burner; G, Gem lamp; tungsten lamps used unless otherwise noted.

Number required	Fixture number	Gas lamps		Electric lamps		Location	Finish	Reflector or globe, type		Fixture height		Ceiling height	
		Number	Kind	Number	Watts			Gas	Electric				
										feet	*inches*	*feet*	*inches*
1	510	1		1	40G	*Attic*	O.C.	None	None				
						First floor							
1	500	3	I.6	3	40	Postmaster's room	L.O.B.	F 7-inch	D 7-inch	9	0	14	0
1	500	2	I.6	2	40	Assistant postmaster	L.O.B.	F	B	9	0	14	0
1	510	1		1	40	Postmaster's toilet	L.O.B.	None	B				
2	501	2	I.6	2	40	Post-office workroom	O.C.	F	B	10	0	19	6
14	510	1	I.4	1	40	Workroom screen	O.C.	F	A				
2	510	2	U	2	40	Workroom on wall	O.C.	F	B				
1	501	3	I.6	3	40	Money-order division	O.C.	F	B	10	0	19	6
5	506	0		1	100	Public lobby	L.O.B.		E 14-inch	12	6	22	0
2	512	0		1	100	Public lobby	L.O.B.		E 12-inch	11	6	15	0
1	505	1	U	1	40G	Lobby desk	L.O.B.	G	G				
						Basement							
2	502	2	I.6	2	40	Swing room	O.C.	F	B	7	0	9	10
1	502	2		2	40	Store room	O.C.	None	B	6	6	9	10
1	503	1		1	40G	Boiler room	O.C.	None	B	6	6	9	10
10	504	0		1	40G	Boiler room	O.C.		None	6	0	9	10
4	510	1		0		Boiler room	O.C.	None					

Height of fixtures. The height of fixtures given in the schedule is the distance from the floor to the bottom of the lowest piece of glassware (reflector or globe) on the fixture. Where no glassware is called for the lowest part of fixture shall determine the height.

A variation of 2 inches either way from the specified height will be the maximum allowed.

Metals. All exposed parts of fixtures are to be made of brass, except where other metals are specified. The composition of brass shall be approximately one (1) part zinc and two (2) parts ingot copper. The composition of bronze metal shall be approximetely: Ingot copper, 90 per cent; zinc, 5 per cent; tin, 3 per cent; lead, not over 1½ per cent.

If the contractor desires to use alloys in lieu of those herein specified, the composition of the same together with finished samples of the metals must first be submitted to the Supervising Architect for approval.

All gas piping and all interior supporting stems of fixtures shall be standard wrought-iron or steel pipe, galvanized.

Castings. All patterns for castings shall be of metal, hand chased, and perfectly finished. The modeling of patterns must be crisp and spirited, true to detail, and uniform in execution.

Castings shall have ample metal for strength and rigidity and for a substantial appearance. They shall be close-grained, free from sand and blowholes, and free from discoloration.

All details of cast ornamentation must be plainly brought out by hand finishing. Where ornaments are made in parts the joints must be brazed and made so as to cause no break in the ornamentation.

Casings, shells, canopies, etc. Casings, spun canopies, and shells up to and including 8-inch diameter shall not be less than No. 20 Brown and Sharpe gauge metal; shells above 8-inch diameter shall be not less than No. 18 Brown and Sharpe gauge metal. Both gauges apply to the thickness of metal before spinning.

Casing shall not in any case be of smaller size than shown on drawing, and in every case must be of ample size to provide room for the wiring.

All tubing must be seamless drawn.

Tubing used as a supporting member of the fixture must not be less than No. 17 Brown and Sharpe gauge.

Canopies, when the dimensions are not given on the drawing, shall generally be 5½-inch diameter at the top and 2½-inch diameter at a distance 4 inches from the top, and in all cases must be made to suit local conditions.

All canopies shall be insulated from the walls and ceilings with fiber rings or plates.

Set-screw collars of canopies shall not be less than $\frac{1}{8}$-inch in thickness, and the collars must fit the stem closely. Set screws of collars shall not be smaller than No. $\frac{8}{32}$ brass screws.

All curved and bent parts of fixtures shall be true and free from kinks or bruises.

All seats between tubings or casings, seating rings, castings, shells, and other parts shall be closely fitted in such manner that all parts are held tight and joints are concealed.

All burrs, fins, and sharp edges must be removed from fixture parts before same are assembled.

Gas piping. The gas piping of fixtures shall be galvanized standard pipe of the following sizes:

Fixture arms	$\frac{1}{4}$
Fixtures up and including 4-4 lights, stems	$\frac{3}{8}$
Fixtures 5-5 to 10-10 lights, inclusive, stems	$\frac{1}{2}$

Ends of gas piping to be reamed to the full area of the pipe, and all joints to be cemented.

Wiring. Fixture wire shall be National Electrical Code standard fixture wire. The carrying capacity of the wiring shall correspond to the National Electrical Code requirements, the size of the wires to be sufficient for supplying one ampere for each socket to which the wire is connected; no wire, however, to be smaller than No. 16 Brown and Sharpe gauge. All sockets shall be wired in multiple.

All joints in wiring must be soldered and well insulated with rubber and friction tape. At all points where abrasion is liable to occur the insulation of the wire must be reinforced with tape or tubing. Except where chain stems are specified, all wiring must be conceled within the fixture construction. The exposed wiring of chain-supported fixtures shall have a silk outer braid of color to match the fixture finish; the wire to be woven in the chain in the most inconspicuous manner.

Reflector and globe holders. All reflector and globe holders (except for cord drops) shall be supported from and rigidly attached to the fixture arm or body, and inclose the sockets unless otherwise shown on drawing. Reflector holders may be omitted where glassware is not specified in the schedule. Holders used with chain pull socket shall have proper size opening, correctly located for chain. All $2\frac{1}{4}$-inch and $3\frac{1}{4}$-inch spun holders, unless otherwise noted on drawings, shall be made of No. 20 Brown and Sharpe gauge metal and have a No. 14 Brown and Sharpe gauge reinforcing ring, not less than $\frac{1}{4}$-inch wide, inside and around the bottom edge of the holder. Edge of holder to be turned over the reinforcing ring, which shall be soldered to holder.

Cast holders shall have the ring for set screws not less than $\frac{3}{32}$-inch thick.

Set screws for $2\frac{1}{4}$-inch and $3\frac{1}{4}$-inch holders shall be not smaller than No. $\frac{8}{32}$ brass screws. Set screws for larger holders shall be of a size proportionate to the weight of the globe to be supported. For all holders up to and including 6 inches, three set screws are to be furnished unless otherwise indicated on drawings, and for larger holders not less than four set screws.

The dimensions of reflector holders and the position of the socket in the same shall be such that the electric lamps or gas mantles specified will be correctly located with reference to the glassware specified.

For globes the holders shall be of such dimensions as to bring the center of the lamp filament or mantle specified in the center of the globe.

All globe holders for globes above 8 inches in diameter shall have four $1\frac{1}{4}$-inch holes in same for ventilation and shall be provided with flat white asbestos discs, full size of globe opening, securely fastened to the underside of holders.

Switches. Pendant push-button switches, single-pole, single-point, 5-ampere, 125 volts, National Electrical Code standard, shall be provided for all pendant fixtures in the post-office workroom and where shown on fixture drawings unless otherwise noted in schedules. An insulating bushing is to be provided at bottom of fixture shell for cord connection to switches. Switches to have sufficient length of National Electrical Code No. 16 Brown and Sharpe gauge silk-covered reinforced lamp cord to bring same within 6 feet 6 inches of floor. Color of cord to harmonize with finish of fixture. All pendant switches to be finished to match the fixtures.

Cord drops. Cord drops shall have sufficient cord to bring the lamps within 6 feet of the floor, and shall be fitted with National Electrical Code standard $\frac{3}{8}$-inch Edison-base key sockets, 7-inch metal cone or bowl-shaped reflectors, and holders adapted to same. Porcelain shell sockets to be used in basement unless otherwise noted in schedule.

Interior of reflectors to have an aluminum brush finish; exterior to have a green enamel finish. Ends of conductors to be flushed with solder and the conductor so secured that no weight will be supported by any electrical connection.

Insulating joints. Insulating joints of molded mica or other approved material and malleable iron or corrugated steel, and of the combination, electrolier or bracket type, as may be required, shall be provided for all fixtures. Insulating joints having soft rubber in their composition will not be approved. They must not in any case project more than $2\frac{1}{4}$ inches from walls or ceilings.

Sockets. All metal shell sockets shall be National Electrical Code standard $\frac{1}{8}$-inch Edison-base type, and where not entirely concealed by the glassware holders shall be finished to match the fixtures. Sockets shall be of the key type for all cord drops and pendant fixtures, except where drawings show keyless sockets are to be installed. Chain-pull sockets to be furnished for all brackets and standards. Both keys and chains shall be outside of glassware holders.

Gas burners. All "gas only" and combination fixtures shall have 5-foot lava-tip gas burners unless otherwise noted. Pendant fixtures denoted in schedule (under "Number of Lamps") with the symbol "I. 6" are to be equipped with "Welsbach Reflex No. 6" burners; bracket fixtures denoted with the symbol "I. 4" are to be equipped with "Welsbach Reflex No. 4" burners, having glassware harmonizing with electric arm; fixtures denoted with the symbol "U" are to be equipped with "Welsbach Junior" burners. All burners designed for mantles shall have pilot burners, by-pass, and chain pulls for same.

Finish of fixtures. The finish of fixtures is noted in schedule, and it must be produced in the most durable manner, by electroplating and acid bath processes. No paints or pigments shall be used to produce any finish.

Oxidized copper finish is to be a dark copper color; tone to be even and to be obtained by hand scouring.

Brush brass finish is to be a yellow brass color, the metal being highly polished and then brushed or scoured to produce an evenly scratched surface.

Light oxidized brass finish is to be similar to above, except that the surface is to be oxidized to a dark color before scouring, enough of the dark color being left in the scouring operation to make it scarcely visible on casings, bodies, and other high surfaces. while low portions of both spun and cast ornaments are to be left dark.

All finishes shall have an even coat of lacquer.

Upon application to the Supervising Architect, samples of the various finishes above described will be forwarded to the contractor for his guidance.

GLASSWARE

Glassware must be free from flaws of all kinds, and is classified as follows:

Type A. Reflectors $4\frac{1}{4}$ inches to $5\frac{1}{4}$ inches in height, concentrating type, giving a downward distribution and apparent maximum candlepower between the angles of 15° and the vertical axis.

Type B. Reflectors 4½ inches to 5 inches in height, extensive type, giving a downward distribution and apparent maximum candlepower at about 45° from the vertical axis.

Type C. Reflectors 5 inches to 6 inches in height (unless otherwise specified), extensive type, giving a downward distribution and apparent maximum candlepower at about 45° from the vertical axis.

Type D. Globes up to and including 7-inch diameter, 3¼-inch holder.

Type E. Globes 8-inch diameter and above, with holders to correspond to diameter of globe.

Type F. Glassware for gas burners and mantles.

All upright mantle burners shall be provided with sand blasted or acid-etched upright shades approximately 3½ inches diameter at the top and 4 inches in height.

Inverted mantle burners shall be provided with globes or reflectors harmonizing in shape, finish, and design with the electric glassware on the same fixture. The glassware for "Reflex No. 4" will be furnished complete with the lamp.

Type G. Special glassware as shown on drawings.

Reflectors. All reflectors must give a symmetrical reflection about the vertical axis. Reflectors (except metal reflectors for cord drops) shall be made of translucent glass, approximately bowl-shaped, and with outlines and surface patterns of an artistic but not a fancy character. The designs or patterns shall not be etched on nor cut in the glass, but shall be pressed or molded in the same. The interior surface of the reflectors shall be smooth. Reflectors shall be colorless or some shade of white. All reflectors of the same type shall be uniform as regards dimensions, patterns, distribution curves, etc.

Globes. All globes shall be sand-blasted or acid-etched on the outside, the degree of sand blasting or etching to be such that the absorption of light by the globes will not exceed 25 per cent.

Globes of type E when specified for pendant fixtures shall be cut in accordance with design No. 63 and be provided with a ½-inch hole in bottom for ventilation

All globes of same size shall be uniform as regards shape, dimensions, cutting, and surface

The contractor must replace all glassware installed by him which may be broken or damaged prior to time of final inspection, as all glassware must be complete and free from all defects at time of final inspection.

Lamps and mantles. No electric lamps or gas mantles are to be furnished under this contract.

Installation of fixtures. All fixtures shall be hung from the gas piping of the building or from fixture studs.

All pendant fixtures must be plumb, and bracket fixtures at right angles to walls.

Inspection and test of fixtures. Preliminary inspection of lighting fixtures will be made by a representative of the Supervising Architect at the shops where manufactured, upon receipt by the Supervising Architect of contractor's notice of readiness for same. This shop inspection will consist of the examination of one fixture of each design *unassembled*, and one fixture of each design *assembled*, the assembled fixture so inspected to be tagged for identification at the building when shipped.

After the contractor has received notice from the Supervising Architect that the shop inspection was satisfactory, or has complied with the demands of the latter in relation to correction of defects noted as the result of shop inspection, the fixtures are to be shipped whenever conditions at the building (as determined by the contractor and superintendent) warrant.

Any action taken as the result of shop inspection must not be construed as acceptance of the fixtures, which is subject to their meeting fully all specification requirements at time of final inspection at the building.

The Supervising Architect reserves the right to waive the shop inspection.

After the third test has been made on the gas piping system (as specified under head of "Gas Piping" in the specification) and certified as satisfactory by the superintendent, the lighting fixtures may be hung and attached to the gas piping when other conditions at the building (as determined by the contractor and superintendent) warrant.

After the fixtures have been connected to the gas piping the entire gas piping and fixtures must be tested and proved tight under an air pressure of 3 inches of mercury. Test pump and gauge must be furnished by the contractor.

After fixtures are connected to the wiring system of the building, the entire wiring system and fixtures must test free from short-circuits and grounds and show an insulation resistance between conductors and between conductors and ground, based on maximum load, not less than the requirements of the latest edition of the National Electrical Code, counting each lamp as one-half an ampere and all lamps in service.

ELEVATORS

WITH SPECIAL REFERENCE TO INSTALLATION IN FEDERAL BUILDINGS UNDER CONTROL OF THE TREASURY DEPARTMENT

In deciding upon the number, type, and speed of elevators for modern structures, architects have not been giving the subject the careful preliminary study which its importance demands, and the unfortunate results may be noted in many recently-erected buildings with an elevator equipment that has proved wholly inadequate.

With the aid of individual experience and judgment, a close approximation of the number of elevators which should be installed in a given building may be based on the following facts in regard to elevator service as stated by Mr. R. P. Bolton, a prominent consulting engineer of New York City, in his excellent treatise entitled "Elevator Service."

Tenants object to waiting more than thirty seconds for a car, or, in other words, demand a schedule not exceeding thirty seconds.

The occupancy of first-class office buildings in large cities will vary from one tenant for 100 square feet of rentable floor area in brokers' offices to one tenant for 150 square feet in office buildings devoted to real estate agents, etc., on the less important streets. In first-class apartment houses it will average one tenant to 300 square feet rentable floor area, and in modern high-class hotels one to 240 square feet. For preliminary calculations for the average office building with mixed tenancy, one tenant to 150 square feet may be assumed.

The rentable area in an average office building is generally 60 per cent of the gross area.

The maximum passenger-carrying capacity of an elevator is reached when the car stops at 80 per cent of the number of floors which the elevator is designed to serve.

An elevator should be designed on the basis of making 80 per cent of its landings to handle the tenants of the building one way in one-half hour, if their occupations are of a character which indicate that the majority will begin and stop work at about the same time.

The average load carried by the elevator is squal to 40 per cent of the number of floors served multiplied by 150 pounds.

The speed of local elevators in a modern office building of more than ten stories should be at least 400 feet per minute, and the speed of express elevators should be approximately 600 feet per minute.

In estimating the round-trip time of an elevator it has been found that approximately six seconds is required to receive and discharge each passenger: and to this should be added nine seconds for time lost at upper and lower landings in handling gates.

The round-trip time of an elevator in a good office building varies between $1\frac{1}{2}$ and 3 minutes, depending upon height of building, speed of elevator, etc. As a general rule, the time allowed for a round trip should not exceed $2\frac{1}{2}$ minutes.

With above data, and knowing the gross floor area of a building and the number and height of stories, the elevator equipment and its duty can be determined.

Assume a building with a total gross area of 130,000 square feet and a height of 156 feet above the first floor, divided into thirteen stories. The rentable area will be about 60 per cent of 130,000 or approximately 80,000 square feet. Assuming an occupancy of one tenant to 150 square feet, the number of tenants to be handled by the elevator in one-half hour is 533, or 1,066 per hour.

There being twelve landings to be served above the first floor, the number of passengers per trip one way each elevator will be 80 per cent of 12 or, say, ten passengers. As each elevator will on an average take ten persons per trip, it is necessary to know the round-trip time to arrive at the capacity per hour. Ten passengers will require sixty seconds to enter and leave car, to which must be added nine seconds for time lost at terminal landings, plus actual running time. The speed in this example will be assumed as 400 feet per minute, or an average speed of 5.33 feet per second, making due allowance for retardation, etc.

To run 156 feet × 2, or 312 feet, the time will be $312 \div 5.33$, or, approximately, 50 seconds; and the total time will be $50 + 60 + 9 = 119$ seconds, or about 2 minutes, which is well within the limit set of $2\frac{1}{2}$ minutes for a round trip. This speed will give approximately thirty round-trips per hour and each car will then handle $30 \times 10 = 300$ persons; and as the total number of persons is 1,066 per hour, four elevators will be sufficient. The schedule will be the round-trip time divided by the number of elevators, or 2 minutes divided by 4 giving 30 seconds, which is the schedule desired

The area of the car floor in the example given would be $10 \times 2 + 4 = 24$ square feet, as an allowance of 2 square feet is made for each passenger and 4 square feet for the operator. The car should be close to 6 feet 0 inch, measured between rails, and 4 feet 0 inch deep. The average number of passengers carried per trip will be 40 per cent of the number of floors served, or 12×0.4, say 5; and assuming the weight of each passenger and of the operator as 150 pounds, the result $(5 \times 150) + 150 = 900$ pounds, the average load carried by the elevator.

As a very rough guide in preliminary calculations for Federal buildings one elevator for 25,000 square feet of floor area may be assumed as satisfactory.

Before completing the drawings for a given building it is advisable to take up the elevator problem with some first-class elevator company, as the elevator equipment is a strong factor in the successful administration of a building, especially an office building.

In his treatise, hereinbefore referred to, Mr. Bolton brings out certain points about elevator service which are frequently overlooked by architects and engineers. At least two of these points should be always kept in mind, i.e., that in high buildings the elevators should be capable of quickly emptying the upper floors in case of a fire; and that in the design of any plant sufficient reserve capacity should be allowed so that elevator repairs may be made during regular working-hours without inconvenience to the occupants of the building.

The elevators should always be grouped, and occupy a prominent position in relation to the building entrance.

Size of cars. As previously stated, in proportioning the size of the platform for passenger elevators for large and tall office buildings, it is assumed that a car will stop at 80 per cent of the landings for which the elevator is designed to stop; that one passenger is estimated to be discharged at each of said floors; and that 2 square feet per passenger and 4 square feet for the operator are allowed in determining the minimum size of car. This size should also be nearly the maximum and the final size of the car should not vary much from this determination, for the reason that a larger car means more passengers, longer stops, and consequently a schedule slower than that for which the plant was designed.

When installing a passenger elevator in an old Federal building where no hatchway was originally provided, the minimum size of car is made 4 feet 6 inches x 4 feet 6 inches. This is an undesirable size and is used only where the conditions demand it.

In old buildings where conditions permit and in all new buildings, the cars are made 6 feet 0 inch wide measured between the rails, and 5 feet 0 inch deep. A wide and shallow car is much more desirable than a square car, or a car with a great depth and a narrow dimension between rails, as passengers have a tendency to crowd to the front of a car. No car should be larger than 6 feet x 6 feet except in a department store, where an 8-foot x 6 feet deep car should be the maximum.

The use of pilasters in cars is not desirable and should be discouraged.

In Federal buildings the cars for freight elevators, mail lifts, and bonded wareroom lifts are made 6 feet x 6 feet, which is the most desirable size. Ash-lifts and hand-power mail-lifts are generally made 4 feet x 4 feet, and cars for electric dumb-waiters 3 feet 4 inches x 3 feet 4 inches.

Elevator hoistways are made 1 foot 1 inch wider than car to allow for the guide rails and 9 inches to 12 inches deeper than car, the front of car being kept 1½ inches away from the entrance threshold.

In office buildings up to 10 stories the car should be 5 feet 0 inch wide measured between the rails and 4 feet 4 inches deep. From 10 to 15 stories the cars should be approximately 6 feet 0 inch wide and 4 feet 4 inches deep; and from 15 to 19 stories, if all elevators are local, the cars should be approximately 6 feet 6 inches wide and 5 feet 0 inch deep.

In the average first-class office building, or in a Federal building, the cost of the ornamental car should range between $300 and $500. Any increase over $500 is extravagant, as, for instance, in installing special, solid bronze cars. The electroplating of iron is just as satisfactory and much cheaper.

Emergency exits should always be specified for passenger cars. If cars are in a separate hatchway, the emergency exit should be in top of car, and where two or more cars are in the same hatchway, emergency exits should be provided from one car to another.

A car with two entrances is dangerous and objectionable. When conditions demand, two opposite entrances, a collapsible gate or sliding panel in the car should be used at the entrance further from the operator; and entrance door and gate on car should be operated by an approved device, which on electric elevators should be made interlocking with the controller. If the entrance to the car are on adjacent sides, the entrance gate further removed from the operator should be protected by some device which, on electric elevators, should be interlocking with the controller.

Speeds. The determination of the speed at which a car should be operated is a matter of judgment, and is governed by the rise of the elevator, whether the service is express or local, the number of stops, and the time taken to discharge passengers.

In apartment houses the car speed under ordinary conditions should be not over 200 feet per minute.

In department stores the speed should not exceed 250 feet per minute nor should it fall much below that where cars stop at each landing up and down.

In hotels higher speeds should be used, depending on the height of building.

In office buildings below 10 stories in height, the speeds will vary from 200 to 400 feet, while with 10 to 15 stories a speed of 400 feet should be allowed.

Express elevators equal in number to the local elevators should be used in practically all buildings sixteen stories high and over, and in very tall buildings may be run at 700 feet to 800 feet per minute until they reach their first landing. In very tall buildings where the ground area is small it is better to run all elevators local rather than to have part local and part express. In New York City 500 feet per minute is the legal limit of speed for local elevators and 700 feet per minute for express service. An elevator is rated as "express" when it has a clear run of 80 feet without a stop.

Federal buildings are nearly always low, and consequently elevator speeds are compratively low. The following are used:

	Travel of car	Speed in feet per minute
Passenger Elevators	30 to 40 feet	200
	45 to 70 "	250
	75 and over	300
Freight Elevators	25 to 35 "	100
	35 to 75 "	150
	75 and over	200
Electric Dumb Waiters	30 and over	100
Hydraulic plunger mail and freight lifts	10 feet	25
	30 "	50
	Over 30	100

Loads. The maximum load to be lifted by any passenger elevator should be arrived at by allowing 75 pounds for each square foot of car floor area. The speed-load should be based on about 80 per cent of the above loading.

Strictly freight elevator loads can be determined only upon detail knowledge of the duty the elevator is expected to perform.

Nearly all office buildings have one or more passenger cars designed for lifting safes, which ordinarily will not weigh in excess of 6,000 pounds each.

The standard passenger elevators in small Federal buildings have a speed load of 1,800 pounds and a maximum load of 2,200 pounds.

Freight elevators in Federal buildings never have a capacity of less than 3,000 pounds, and the load in large cars is usually based on 100 pounds per square foot of car floor area.

Hydraulic plunger lifts for freight and mail are seldom designed for a capacity of less than 2,000 pounds. Where a hydraulic plunger lift must be operated with city water pressure at about 50 to 60 pounds, and structural conditions prevent counterweighting, the load is reduced to 1,000 pounds.

The capacity of hand-power mail-lifts and electric dumb-waiters is made 400 pounds.

The hand-power freight-lifts used cover about the following range:

3 x 3 platform	500 capacity
4 x 4 platform	800 capacity
5 x 5 platform	1000 capacity
5 x 6 platform	2000 capacity

A hand-power freight elevator is installed only as a last resort, and is not advisable.

Types of elevators. Hydraulic passenger elevators, except the plunger type, which is especially popular for department stores, have practically given way to electric elevators which are now generally used under all conditions where direct current is available, and have reached a high plane of safety and efficiency.

The hydraulic freight elevator has a limited field, and generally confined to the short-rise plunger type, which gives a rugged and generally satisfactory elevator when operated at moderate speed.

The hydraulic-plunger passenger elevator is very satisfactory for a rise of not over 150 feet, and for speeds not in excess of 350 feet per minute. The pressure-tank system should be used with this type of elevator and the water-pressure carried should be 100 to 175 pounds per square inch.

The horizontal low-pressure hydraulic pushing or pulling type, the vertical low-pressure hydraulic pulling type, and the still older steam type of elevators are seldom installed.

The leading elevator builders do not recommend the use of alternating current for passenger elevators when the speed exceeds 250 feet per minute, nor the use of single-phase current for any elevator with a motor in excess of 15 H.P. For a tall building where an isolated generating plant is not to be installed and only alternating current is supplied by the local company, they recommend the installation of direct current elevators operated by motor-generator sets which will transform the alternating current into direct current. The claim is made that the operating cost with this outfit will be less than for hydraulic elevators except in climates where exhaust steam for heating is required the year around and in department stores where the speed should not exceed 250 feet and elevators make all stops and the rise is short.

If direct current is available, and investigation shows that no special conditions demand hydraulic equipment, the selection of the elevator mechanism involves only the selection of the particular type of machine best suited to the service.

In commercial practice, the standard, single screw, electric, drum machine is recommended for passenger service for speed loads varying between 1,600 and 2,000 pounds and for speeds ranging from 100 to 175 feet per minute.

The standard double-screw, electric drum machine is recommended for passenger service for all loads from 2,000 to 4,500 pounds, and for speeds from 175 to 300 feet per minute. This type of elevator is almost exclusively used in Federal buildings. These machines may be arranged for back gearing so that they can handle 6,000 pounds or more in buildings where safes must be handled.

The single and double-screw machines should be placed in the basement unless special conditions forbid, in which case they may be located over the hoistway.

The worm-gear traction machine is recommended for speed loads ranging from 1,600 to 4,500 pounds, and for speeds ranging from 250 feet per minute as a minimum to 400 feet as a maximum. These machines may be back-geared so that heavy loads like safes may be lifted. When the machine can be located at the top of the hoistway, and the speed of car is 300 feet per minute or more, this type of elevator is strongly recommended in preference to the single or double-screw drum machines. It may also be located in the basement if desired. Its cost is about 10 per cent more than the double-screw drum type.

The worm-geared traction type of elevator possesses many points of superiority over the drum machines, among the most important being the feature of the design which prevents over-running of the car or counterweight beyond a predetermined limit of travel; the absence of side leading of cables; the use of ball bearing shackles on all rope hitches, preventing torsional strain on cables; and the use of oil or spring buffers under both the car and the counterweights. Spring buffers are used when the speed does not exceed 300 feet per minute.

The gearless traction type of machine which is the latest and most satisfactory production of the elevator industry, is recommended for use in all cases where the speed loads vary between 1,600 and 3,500 pounds and where the speed is to be 400 feet and over. There is practically no limit to the speed of these machines and in express service they can readily be operated at 800 feet per minute.

The two-to-one gearless traction type of elevator may be used under the same conditions as given above for the worm-gear traction type, with the addition of a traveling sheave placed on both car and counterweight. This type of elevator is being used to advantage between the given limits of speeds as applied to the worm-gear traction machines where economy in current consumption is a governing feature.

These machines should always be located at top of hoistway, though it is possible to place them in the basement.

For lifting heavy loads the speed is reduced by special appliances and an extra brake installed.

Adjustable counterweights may also be used with the wormgear traction and the gearless type machines so that 6,000 to 7,000 pounds loads may be handled.

The gearless type elevator costs more than the other electric types, but is considerably more efficient.

When the only current available is single-phase other than 60-cycle, special consideration must be given to the type of elevator to be used, as definite practice has not been established for guidance in such cases, although elevator manufacturers are rapidly advancing along this line.

In Government practice, low-rise freight elevators, and mail, ash, and bonded-wareroom lifts are made direct plunger hydraulic. A lift is always provided for a bonded wareroom. In the large Federal buildings provision is made for the installation of a direct-acting plunger ash-lift or an electrically operated ash conveyor.

Where the post-office workroom floor is more than 5 feet 0 inch above grade of driveway, hydraulic plunger elevators are installed to handle mail. When special conditions demand, in the small buildings, hand-power elevators are installed to handle mail.

In Federal buildings three or more stories in height, especially when a court room is on second or third floor, provision is made for the installation of one or more electric passenger elevators.

Owing to the many special conditions imposed by each layout, it is difficult to predict the efficiency of electric elevators from line to load, but as a rough rule it is safe to say that the efficiency of the double-screw drum machine will average 50 per cent; the worm-geared traction machine, 55 per cent; and the gearless traction type, 65 per cent.

The kilowatt consumption per car mile is dependent on the number of stops, but for drum machines in Federal buildings it will usually average 5 kilowatts per car mile.

The car travel in office buildings will range from 10 to 20 car miles per day, the latter figure being the average for a well-occupied building. In the Singer Building in New York City it is stated that the tower elevators will each average thirty miles per day.

In the ordinary Federal buildings the travel for each passenger elevator will average eight car miles per day, and the average cost of current for an electric elevator will be $25.00 per month. In the largest cities the car travel will average nearer twelve car miles per day.

In the operation of hydraulic elevators 8 water horse power per car mile is a fair average.

To ascertain the approximate size of the horse power of the motor for an electric elevator multiply two-thirds of the maximum load by the speed in feet per minute and divide by 16,000. Except under special conditions an elevator should not be over-counterweighted more than 40 per cent of the maximum load.

Space requirements, etc. When elevators of any type are placed at the top of hoistway a 7-foot 6 inch clear space should be allowed to nearest point of roof or to the underside of pent-house. This should be increased to not less than 10 feet 0 inch wherever possible, and an I-beam trolley rail with chain fall installed to facilitate the handling of elevator parts during erection or repairs.

The minimum distance to allow from the top landing to top of machine beams for overhead traction elevators is 17 feet 0 inch when the speed does not exceed 400 feet per minute, and 19 feet 0 inch when the speed is in excess of 400 feet.

In Federal buildings where the drum type of elevator is used the minimum distance from the top landing to the underside of lowest point of roof is made 21 feet.

With counterweighted plunger elevators and electric dumb-waiters the minimum distance allowed from the top landing to the lowest point of ceiling or roof is 14 feet 0 inch.

The overhead clearance for electric elevators of all types is one of the most important safety items and in Federal buildings it is never made less than 3 feet 0 inch, the distance being measured from the top of the car shoes.

The distance from the car floor to the top of the shoes is generally 10 feet 7 inches, but under unfavorable conditions the crosshead may be sunk into the roof of cab and this distance reduced to 9 feet 7 inches.

The minimum depth of pit for any electric drum elevator should be 3 feet 6 inches for direct-current and 4 feet 0 inch for alternating-current elevators.

The minimum depth of pit should be 6 feet 0 inch where oil buffers are used and 4 feet 0 inch with spring buffers.

When worm-geared traction elevators are located at top of the hoistway the rear wall of pent-house may be carried up about flush with the rear line of hoistway. At the front of the elevator a space at least equal to the depth of the hatchway must be allowed for the machine, and at each end of the elevator bank a space equal to at least one-half the width of the hoistway of one elevator should be allowed.

The most fertile source of trouble in installing elevators is the failure of architects and engineers to make proper allowance of space for the installation of the machinery and too much importance cannot be attached to this feature.

The location of an elevator machine directly under the hatchway is extremely poor practice and should be avoided unless space conditions forbid any other course, or the use of auxiliary leading sheaves would be necessitated by locating machine outside of hoistway.

In Federal buildings where it is necessary to locate a machine under the hoistway, the minimum distance from machine room floor to under side of the pit-pan at first floor is made 8 feet 6 inches; and where conditions will permit of lowering the machine room floor, the distance is made 9 feet 6 inches.

Where the car runs to basement and the hoistway is enclosed in brick walls, the minimum opening in the wall of the shaft for the drum for standard elevators should be 8 feet 6 inches high and 4 feet 0 inch wide and where possible it should be made the full width of shaft and 9 feet 0 inch high.

If natural light is not available at location of overhead work, convenient and ample artificial illumination should be provided.

Particular attention should be given to the fact that the inside edge of entrance door thresholds must be absolutely plumb from top to bottom so that the distance from car floor to thresholds will be the same at all floors. Where conditions require a projection in the hoistway at entrance door, it should not be made sharp but be flared off at a slight angle.

In locating entrance doors to elevators consideration should be given to the fact that the operator should handle the controller with the left hand and open and close the door with right hand. The door should slide from right to left. Special efforts are made in Federal buildings to obtain a first-class hanger and operating device on hand-operated doors.

The minimum width of opening for entrance door for a passenger elevator should be 2 feet 6 inches. The height of entrance doors should always be 7 feet 0 inch. The two-panel entrance door, each leaf opening from the centre, is a first-class door and either this type or the two-third opening door, one panel sliding on the other, should be used wherever possible, as the service of an elevator is materially affected by the size and type of the entrance door.

The entrance door should be as light as possible in weight, and be placed close to hoistway so that the operator does not have to let go of the controller in order to operate the door. Where the entrance door is heavy, or where the service is heavy and speed of operation is an item, the compressed-air system of door handling is installed.

The elevator machine (especially if for alternating current) should be installed in a machine-room with brick enclosing walls to reduce the noise to a minimum.

For each passenger and freight elevator, a grating designed to support a load of 75 pounds per square foot should be placed beneath the overhead work.

The best overhead grating is made of 2-inch channel irons with perforations set so that a 1-inch space exists between channels.

On all electric elevators with lift of 15 feet 0 inch or over, and on hand-power elevators on which persons may ride, a safety device which will become operative upon breaking of hoisting cables should be installed. For 15 feet 0 inch to 20 feet 0 inch lifts, the quick-acting type which acts immediately upon attaining excessive speed or upon breaking of hoisting cables should be used. For lifts over 20 feet 0 inch the regular guide grip safety device actuated by a centrifugal governor should be used.

Attention should be given to the design of the enclosing grille work of elevator hoistways and every effort made to have all openings below door transoms kept down to 1½ inches in width which will conform to the best practice in this respect.

The platforms of all freight and mail lifts should be enclosed on three sides and have a ceiling. The distance from floor to ceiling of enclosure on platform should be 7 feet 0 inch. The lower part of enclosure should be ⅛-inch sheet iron or lighter weight corrugated iron, and upper part and ceiling No. 9 B.W.G. galvanized wire with 1-inch diamond mesh.

To operate the sidewalk doors, in connection with an hydraulic plunger lift, in Federal buildings, 4 rods are attached to the underside of the cover. These rods are of sufficient length to extend into four (4) 2-inch pipe uprights, attached to the lift platform. On the rods under the cover heavy rubber or spring buffers are placed. The cover is made of ⅛-inch sheet steel in one piece. In lieu of this, a bow or bale is sometimes placed on the elevator platform to operate hinged double-leaf doors at side walk level.

When it is necessary to place an hydraulic elevator in an exposed location subject to freezing temperature, some non-freezing mixture should be used as the operating medium instead of water. In plants where oil is used a weighted accumulator should be installed instead of the usual pressure tank. In Federal buildings all car and counterweight guides for passenger and freight elevators, hydraulic lifts, and electric dumb-waiters are steel. Car guides are not less than 4½ inches x 3⅜ inches, weighing not less than 14 pounds per foot; counterweight guides weigh not less than 7 pounds per foot. The car guides are backed up with 7-inch channels weighing 9½ pounds per foot.

For hand-power lifts the car and counterweight guides are kiln-dried maple.

To ascertain the strain on the supporting beams with the elevator machine located at the top of the hatchway, the weight of the standard double screw machine is taken at 15,000 pounds in Federal buildings.

In designing the overhead supports, the live loads are doubled and added to the dead loads and the calculation for supporting beams is based on a fibre strain of 8,000 pounds in the section used.

Mechanical dial indicators should be installed in small buildings having one or more elevators. In buildings requiring three or more elevators in one group, the flashlight-signal system should be installed, with mechanical dial indicators on the first floor. The flashlight signal system will increase the capacity of a passenger elevator plant approximately 10 per cent, and is worthy of serious consideration.

Cables and counterweights. Swedish iron hoisting and counterweight cables are used in commercial practice, and also in Government practice, except where special conditions render it advisable to use "steel" cables. The use of ropes larger than ⅝-inch diameter is not desired unless loads exceed safe working strain. The following table is used in selecting cables for passenger elevators:

Diameter of Cable	Min. diameter of sheave in inches	Max. load in lbs.
½	20	1,100
9/16	22	1,350
⅝	25	1,700
¾	35	2 500
⅞	45	3,200
1	55	4,000

For freight elevators the above loads may be increased 25 per cent.

Never less than four (4) hoisting cables are installed on an hydraulic passenger elevator or on a worm-geared traction machine.

Six cables are used on the gearless type of machine and the same number on the drum machine. In the latter case two are for hoisting, two for car counterweight, and two for the back drum weight.

To determine the load on the hoisting ropes of a drum-type electric elevator, the maximum load is added to the estimated weight of car and safety device, and from this total the car counterweight (which will be about two-thirds of the weight of safety plank and car) is deducted.

Under normal conditions, in Federal buildings, the car and safety will weight about 3,200 pounds, and the maximum load 2,200 pounds; the pull on the ropes will then be (3,200 plus 2,200)—2,200 equals 3,200 pounds, which will be safe for two $\frac{5}{8}$-inch ropes.

To ascertain the weight of the drum counterbalance one-third of the weight of the car and safety is added to one-third of the load.

A car counterweight is always provided unless car is very small and speed does not exceed 200 feet per minute.

The cars for cable-operated hydraulic elevators are counter-weighted up to within 600 or 800 pounds of the weight of car for speeds up to 400 feet per minute. In the low-rise hydraulic plunger elevators with speeds up to 50 feet per minute the counterweights are within 500 pounds of the weight of the car and plunger, and for 100 feet per minute within 800 to 1,000 pounds of the weight of the car and plunger. The average weight of a low-rise plunger with a 6-foot x 6-foot car is about 2,000 pounds.

Where the car travel exceeds 90 feet, a chain counterbalance is installed to offset the weight of cables. A braided cotton rope is threaded through the links of chain to reduce noise, or the chain is covered with canvas sewed on and painted.

Two $\frac{3}{8}$-inch steel hoisting cables are generally used for electric dumbwaiters and usually one $\frac{3}{8}$-inch counterweight cable. The operating rope on a hand-power elevator is Russian hemp, $3\frac{1}{2}$ inches in circumference. The hoisting ropes on hand-power elevators are iron.

Tanks, pumps, etc. Compression tanks should not be made over 6 feet 0 inch in diameter. The surge tank should be made of the same capacity as the compression tank. A vacuum valve should be placed on all pressure tanks.

In proportioning a system for Federal buildings, especially where a small motor-driven pump is to be installed, a large tank and a small pump are used. The large compression tank reduces the frequency of starts of the pump to a minimum and enables a few trips to be made with pump out of service. The compression and discharge tanks are made not less than twelve times the capacity of the cylinder or cylinders in small installations, and between eight and ten times the capacity of all cylinders in large installations.

The resultant pressure with pump out of service and tank up to maximum normal pressure, after drawing a given quantity of water, is calculated on the basis of Mariott's law. Assume a tank of 1,000 gallons capacity, containing 600 gallons of water and 400 gallons of air, and that the pressure in tank is 100 pounds and we desire to withdraw 80 gallons and determine the resultant pressure. The absolute pressure at start is 100 plus 15 equals 115 pounds, and the amount of air is 400 gallons; then multiply 400 by 115 and divide by 480, and from the result deduct 15 pounds which will give the resulting pressure in tank.

When the hydraulic elevators are scattered, an auxiliary compression tank is placed near each group of elevators. This practice is strongly recommended by the leading elevator companies.

When an hydraulic plunger elevator is operated by city water-pressure direct, and the street pressure is only about 50 to 60 pounds a large steel reservoir is placed near the operating valve.

Pumps for passenger and important freight service are so proportioned that they will restore to the pressure system the quantity of water used by the elevators during the period of a round trip, which in Federal buildings is assumed to be not less than one minute nor more than two minutes.

Where the steam pressure generated in the building is 100 pounds and over, it is the practice to install compound steam pumps. In very large jobs, three pumps are used, two large enough to handle the maximum travel and one in reserve. Ten per cent is allowed in all pump calculations for slip. When two pumps must be used, each one is made capable of maintaining the schedule plus 10 per cent. When three pumps are used and two are in service, the pressure governor of one is set about 20 pounds lower than the other so that the second pump comes into service only in case of excessive demand.

Where eight (8) hydraulic elevators, or more, are installed and the pumping duty exceeds 500 gallons per minute for each pump, the high-duty fly-wheel pump or the triple-expansion duplex pump is used, if steam pressure is not lower than 135 pounds. One high-duty pump may be installed for day load and a smaller compound pump or pumps for reserve and night load. In the unimportant pumping installations, say for one mail and one freight lift, the total pump capacity per minute is made equal to the total hydraulic plunger displacement and a triplex pump is selected to supply that amount of water at 40 revolutions per minute.

The operating valves for short-rise low-speed direct plunger lifts usually vary in size from 2½ inches to 4 inches, depending upon the water pressure and speed of the lift. In each case the area through the valve is equal to the corresponding size of pipe. The size of the valve largely governs the speed of the lift; and it is desirable to install valves and piping of such size that the velocity of water through them will be about 10 feet per second, except where the pressure is low or water is taken from city water-mains direct, in which case a speed of 5 or 6 feet per second should not be exceeded. Under no conditions should a speed of 14 feet per second be exceeded in the supply of piping.

In calculating plungers for standard hydraulic elevators, the total loss of pressure between the elevator pressure tank and the cylinder is assumed to be 15 pounds per square inch, provided the elevator is located reasonably close to the pressure tank.

The standard sizes of plunger for direct hydraulic plunger lifts used are as follows:

Inches	Inches	Inches	Inches	Inches
4½	6½	8½	10½	12
5½	7½	9½	11	12½

The cylinders are usually 1½ inches larger inside diameter than the plunger; and the cylinder casing is 5 inches larger inside than the plunger diameter.

In estimating the size of cylinders for the old style pushing and pulling type of hydraulic elevators, the following efficiencies are used.

Ratio of gearing..	3:1	4:1	5:1	6:1	7:1	8:1	9:1	10:1	12:1
Approximate efficiency......	0.85	0.80	0.75	0.70	0.68	0.65	0.62	0.60	0.55

These efficiencies, however, vary somewhat with the size of the cylinder and conditions under which they are installed.

The efficiency of a direct hydraulic plunger lift is usually taken at about 90 per cent when compensating counterbalance cables are used, and the same efficiency may be assumed when the ordinary counterbalance ropes only are installed if it be remembered in the calculation that the overbalance must be about 500 pounds plus the weight of 1 foot of the plunger.

The following are examples of small direct plunger hydraulic lift plants which are giving satisfaction in Federal buildings:

1. Two direct-plunger hydraulic lifts with platform 6 feet 0 inch x 6 feet 0 inch, counterweighted to within 500 pounds of weight of platform and plunger; lift 23 feet 9 inches; water pressure in tank 100 pounds; speed of lifts 50 feet 0 inch per minute; maximum live load to

be lifted, 2,000 pounds; efficiency of lift taken at 90 per cent; loss in pressure from tank to cylinder, 15 pounds: $\frac{(2000 + 500) \times 0.9}{85} =$ area of plunger, 33 square inches, which is the area of a plunger $6\frac{1}{2}$ inches in diameter; plunger displacement 33 square inches area x 23 feet 9 inches long equals 41 gallons per trip; compression tank 5 feet 0 inch x 12 feet 0 inch long equals 1,800 gallons; discharge tank 6 feet 0 inch wide x 8 feet 0 inch long x 5 feet 0 inch deep, equals 1,800 gallons capacity. Ratio tank capacity to total cylinder displacement, 22:1; two pumps each capable of discharging 40 gallons per minute against 100 pounds; motor horse-power equals 5 each, ratio of total pump displacement to total cylinder displacement in this case, 100 per cent.

2. One freight lift with plunger $10\frac{1}{2}$-inch diameter and 26 feet 0 inch lift (not counterweighted).

One mail lift with plunger 15-inch diameter and 15 feet 4 inches lift (not counterweighted).

One registry lift with plunger $8\frac{1}{2}$-inch diameter and 15 feet 4 inches lift (not counterweighted).

Total displacement of the three plungers equals 41 cubic feet; pressure in tank 100 pounds; tanks 5 feet 0 inch diameter by 18 feet 0 inch long, each containing 370 cubic feet; ratio of compression tank to total cylinder capacity, 9:1; two pumps each designed to deliver 80 gallons per minute; ratio of total pump capacity to total plunger displacement, 1:1.9, horse-power of each pump motor.

$$\frac{80 \times 100}{1700} \times 2 = 10.$$

The following is an example of calculating an horizontal hydraulic pushing type of elevator such as were formerly installed by the office:

Car floor 6 feet 0 inch x 5 feet 0 inch equals 30 square feet; maximum live load 30 x 75 equals 2,250 pounds at speed of 200 feet per minute; schedule 1 minute; travel 64 feet; underbalance 800 pounds; maximum tank pressure, 100 pounds; loss of pressure in valve and pipes, 15 pounds; minimum pressure in elevator cylinder, 85 pounds; geared 8 to 1; stroke 8 feet 0 inch; load equals $\frac{(2250 + 800)}{0.65} \times 8$ equals 37,500; cylinder equals $\frac{37,500}{85}$ equals 441 square inches; diameter of cylinder equals 24 inches; cylinder capacity, 190 gallons; pump 190 plus 10 per cent equals 210 G.P.M. at 50 strokes per minute; a 1,600-gallon compression tank and a surge tank of similar capacity is used.

The following is a description of a proposed hydraulic plunger lift installation for a Federal building:

Seven plunger elevators are to be installed, six of which are to have platforms 6 feet 0 inch wide and 19 feet 0 inch long and the seventh a platform 6 feet x 5 feet. The large elevators are to have a capacity to lift 5,000 pounds at an up-speed of 100 feet per minute, and a down-speed of 125 feet per minute. The capacity of the small lift is 1,500 pounds at 125 feet per minute. The travel of the large machines is 32 feet 6 inches and of the small machine 15 feet 0 inch.

The plungers for the large machines are 11 inches in diameter, and for the small elevator 7-inch diameter.

The operating valve for the large machines is 4-inch diameter, and for the small machine 2½-inch diameter. The speed in supply pipes and valves is made 12 feet per second and the discharge pipe from each machine is one size larger than the supply pipe.

Each elevator is provided with a piston valve operated by a hand rope and each machine has an automatic stop valve.

The water pressure used is 150 pounds per square inch.

There are two compression tanks, one located near the pumps and the other in a central location with respect to the elevator groups. The tank near pumps is 3,000 gallons capacity, and the other one is 4,500 gallons capacity. The tanks are tested to 300 pounds pressure.

Near the pumps is one main surge tank which is of the open type and of 6,000 gallons capacity.

Three (3) pumps are installed each capable of discharging at not over 125 feet per minute piston speed 250 gallons of water per minute into the compression tanks at 150 pounds pressure.

Two of the pumps will maintain a 2-minute schedule for all elevators with a liberal allowance for slip and leakage.

Two railroad type of air compressors are used to maintain the air cushion in the compression tanks.

All piping is standard black wrought-iron and all fittings are extra-heavy 800 pounds test. Each of the large machines is provided with a compensating counterbalance consisting of eight 1-inch diameter steel cables. The small machine is not counterbalanced. The large machines are guided in the center as usual and the steel guides are made of 4-inch x 5-inch tee irons.

The following is a brief specification for the standard tandem worm geared electric passenger elevator with full magnet control such as is installed by the office of the Supervising Architect:

ELECTRIC PASSENGER ELEVATOR

Hoistway. The hoistway for the electric passenger elevator will be provided, complete with enclosure and entrance doors, under another contract.

Pit. A pit of 4 feet deep will be provided for elevator under another contract.

Metal grating. A suitable metal grating, capable of sustaining a load of 75 pounds per square foot, must be provided in hoistway immediately below the bottom of sheaves.

Guides. Car and counterweight guides are to be installed under this contract. The car guides are to be cold rolled or planed tees not less than 4½ by 3⅜ inches, weighing not less than 14 pounds per foot. They are to be reënforced with and secured at least every 6 feet by two ⅝-inch tap bolts to 7-inch channels weighing not less than 9½ pounds per foot. The ends of tee guides to be tongued and grooved or doweled to form matched joints, while the channels are to be joined with splice plates. The joints in tees and channels not to occur within 3 feet of each other. The counterweight guides, which are to be of same material as above, but of lighted cross section if desired, may be without reinforcing channels and secured together with fish plates. They are to be installed in hoistway and secured in a substantial manner.

Overhead supports. All overhead work is to be supported on an approved arrangement of steel beams furnished by this contractor; beams to be secured and supported in a substantial manner.

Winding machine. Especial attention is invited to the fact that only machines of standard character and generally recognized merit produced by manufacturers of large experience will be considered. The winding machine is to be of the tandem worm-gear type, with motor and drum mounted on one bedplate. It is to be designed for location at base of hoistway. All parts are to be properly proportioned for strength and rigidity.

Capacity and speed. This elevator must have the capacity to lift a full live load of   pounds, exclusive of weight of car and cables, at a minimum speed of   feet per minute, and a live load of   pounds at a correspondingly reduced rate of speed.

A variation of 15 per cent above this speed is the maximum permissible under all conditions of load up or down.

Travel. The machine must permit a car travel of   feet more or less from   to   floor.

Foundation. A concrete foundation not less than 3 feet deep and of proper size to receive the bedplate of machine must be provided, and anchor bolts of sufficient number not less than $\frac{3}{4}$-inch diameter, with pipe sleeves and bottom plates, are to be built into the foundation.

The exterior of foundation above floor line to be finished with cement mortar troweled smooth.

Bedplate. The bedplate must be cast in one piece, with reinforcing ribs to maintain alignment of all parts secured thereto.

Drum. The winding drum is to be cast iron, accurately turned and grooved for cables. The grooves are to be of sufficient length to accommodate at least one turn of each hoisting and drum counterweight cables, in addition to that required for actual travel of the car. A drum keyed to shaft only will not be permitted. The drum must be either bolted to a flange, a solid part of the drum shaft, or to the gear direct. Drum bearings are to be self-oiling.

Gear. The drum is to be driven through right and left steel worms meshing either with two interlocking bronze worm wheels or with two bronze worm wheels with interlocking spur gears securely fastened to worm wheels. The worms must be set to eiliminate all thrust on the bearings and must drive the gears smoothly and in perfect alignment. The worms must be cut on the solid shaft, keying or pinning on not being permitted. The complete gear is to run in oil in a dust-proof gear case.

Motors. Motor is to be wound for volts direct current. Contractor must verify this before beginning work, and if such current is no longer available, take up the matter with the Supervising Architect. Motor to be of design adapted to elevator service and to be capable of developing the required power and of withstanding temporary overloads of at least 50 per cent and shocks occasioned by frequent starting under heavy loads. Bearings to be self-oiling type. Motor must be designed to operate practically without noise.

Compounding. The motor must be compound wound or of the interpole type to give a high starting torque.

Field coils. Field coils to be form wound and so secured that they may be readily removed without unwinding.

Armature. Armature must have slotted core with windings thoroughly insulated and secured firmly in place. It must be balanced both mechanically and electrically and be well ventilated and easily removable.

Commutator. Commutator must be of drop-forged or hard-drawn copper of highest conductivity, insulated with mica of even thickness and proper hardness to insure uniform wear, and must run free from sparking or flashing at the brushes at any load or during change of load. It must have ample bearing surface and radial depth for wear.

Brushes. Brushes to be of carbon of such cross-sectional area that the current density at full load shall not exceed 40 amperes per square inch.

Brush holders. Brush holders to be of such design that no chattering will result from continuous use. Collective adjustment of brushes to be made by means of rocker, and individual tension to be maintained by a spring. If the motor is of the interpole type the rocker arm may be omitted.

Insulation. The frame of machine must have an insulation from field coils, armature winding, and brushes of not less than 1 megohm. Motor must be capable of withstanding a breakdown test of 1,500 volts alternating current for one minute.

Heating effect. Motor is to be run continuously at full load for two hours, and at the expiration of that time the temperature of the armature and field coils shall not exceed 85° F. and of the commutator 90° F. above the temperature of the surrounding air. Temperatures to be measured by thermometers shielded by cotton waste in a manner approved by department's agent.

Efficiency. Bidders are required to state in their proposal the rated horse-power output of the motor, the efficiencies of which must not be less than per cent at one-half load and per cent at full load. If shunt field resistance is used in making shop test it is to be understood that the losses in the field rheostat will not be included in calculating motor losses.

Shop test. The efficiency, heating effect, installation resistance, etc., of motor shall be determined by actual test in the presence of department's authorized agent, who shall determine the test conditions. The test is to be made at the shop where motor is constructed and to begin within ten days after receipt of notice from contractor of his readiness to commence same. The test is to be at contractor's expense except traveling and other expenses of Department's agent. The Supervising Architect reserves the right to wave the shop test and to require the contractor to submit certified test sheets of motor in triplicate for approval.

Brake. A spring-actuated magnetic brake of sufficient power to stop and hold the elevator under a maximum load is to be provided on worm shaft. The brake must be operated when released by electromagnet, the circuit of which must be opened by the several safety devices so as to apply the brake at both limits of travel; when car attains excessive speed; when car is checked in hoistway while descending; when operator removes bands from car-switch lever or brings it to stop position; when the emergency switch is open; and on failure of current.

Finish of machine. The machine is to be filled, rubbed down, and painted with one coat before leaving the shop. When erected and ready for operation it is to be finished with one additional coat of paint, the tint to be approved by superintendent.

Wrenches. A complete set of wrenches for elevator machinery is to be furnished and mounted in a suitable hard-wood frame, located where directed by the superintendent.

Type of control. The elevator control is to be of the full magnetic type, consisting of an operating switch in car electrically connected with controller magnet which makes the various connections governing direction, acceleration, and speed. Mechanical devices between the lever of the car switch on controller to perform any or part of any of above functions will not be permitted.

Controller. The controller is to consist of a slate panel not less than 1½ inches thick and of suitable dimensions to have mounted thereon solenoids with the necessary contact devices to perform the following operations: (a) Make and break the circuit and reverse the motor under control of the operator without destructive arcing. (b) Lift brake, cut out starting resistance by successive steps, so as to give a gradual acceleration of car, and limit the maximum accelerating current to 35 per cent in excess of the speed load running current, with controller set for five-second acceleration. (c) Cut in resistance in series with the armature in order to attain a dynamic brake in action of appreciable strength and apply brake in stopping. (d) Open the main supply circuit upon failure of current or excessive drop in potential. (e) Prevent the admission of more current than is required to lift maximum load (pounds). (f) Prevent reversal of current in series field.

The resistance used with and forming part of the controller must be properly ventilated, and if supported from controller framing must be in such a manner and position as to give easy and free access to all connections on back of controller board.

All parts must have ample metal for stiffness. Contact surfaces must be so designed so that a positive contact is obtained at every point and not more than 100 amperes per square inch and carried at maximum load. Electrical connections between car switch and controller must be made with best grade, rubber-insulated, flexible, braided elevator cable.

Safety devices. The elevator must be supplied with all devices necessary for safe operation, including the following or their equivalent, which must operate in conjunction with the main brake, viz: guide grips, limit switches, speed governor, slack-cable switch, car-switch stop, and emergency car switch.

Guide grips. Guide grips of first-class design, which become operative whenever the maximum speed limit is exceeded in descending, must be provided on the car. The grips must be operated by a Swedish iron cable passing through a clamping device controlled by a centrifugal governor and around a drum or V-groove sheave under the car. When the cable is clamped the drum or sheave is to be revolved and operate the guide grip by means of screws. The guide grips shall be tested by dropping the car with a net load on the platform of two-thirds of the maximum load. The total distance traveled by the car after the rope has been cut shall be not less than 6 feet nor more than 9 feet. The test is to be made before connecting the cable and may be made before the cage is attached to the platform. It is to be made at the building, in the presence of the department's representative, who will advise the department when a satisfactory test has been made.

Limit switches. The machine is to be provided with limit switches which promptly cut off the motor current when the car travel is exceeded in either direction. In addition to the limit switches operated by drum shaft, limit switches which will open the controller circuit and stop the motor when travel of car is exceeded in either direction must be provided in the hoistway. The hoistway limit switches to open the current through the potential switch and all limits must perform their function.

Speed governor. A centrifugal governor must be provided on the machine to cut off the motor current at determined maximum speed. If this governor is used to operate the guide grip it must perform both operations independently; the motor current to be cut off before the speed at which the guide grips operate has been attained.

Slack-cable switch. A safety switch must be provided for cutting off current if for any reason the car is suddenly checked in hoistway while descending, or upon the breaking of either a hoisting or back-drum cable or both.

Car-switch stop. The car-switch must be provided with an attachment which will bring the switch to stop position if for any reason the operator removes his hand from the switch lever.

Emergency switch. A switch which may be used by operator to open the controller circuit through the potential switch in case of accident is to be provided in car. A cable separate from and similar in construction to the car-switch cable must connect the emergency switch to the controller.

Buffers. Extra heavy spring buffers with substantial footings are to be provided, two for the car and two for the counterweights.

Sheaves. All sheaves are to be of cast iron, of as large a diameter as can be used, grooved for the size cables used, and provided with extra heavy steel shafts. No vibrator sheave to be less than 36 inches in diameter. Bearings are to be of ample dimensions and first-class design and all are to be provided with brass compression grease cups and copper drip pans. Idler sheaves, if used, must be anchored in a substantial manner to machine or to independent steel framing.

Cables. The elevator is to be provided with six cables—two hoisting cables, two drum counterweight cables, and two car counterweight cables. The cables are to be connected to the car and counterweight frames as well as to the drum in the most substantial manner. The cables connected to drum are to be of such length that there will be at least one complete turn of each on the drum at any position of the car. All cables are to be best Swedish iron, standard hoisting rope   diameter, consisting of 6 strands, wound about a hemp core or center.

Counterweights. The car is to be counterweighted directly. The load is to be partially counterweighted at back of drum. The total overweight must not exceed one-third of the maximum load. The weights are to be secured to the frames in such a manner that they can not be jarred out or released by the spreading of the rods connecting the top and bottom of counterweight frame.

Car. The elevator car is to be as large as the hoistway will permit, and must be thoroughly framed, bolted and riveted, and securely braced. The ornamental cage is to be constructed of wrought iron or steel, the lower part to be panel work and the upper part open grille work to harmonize with the hoistway entrance doors. Finish of cage to match enclosure work.

An emergency exit is to be provided in the roof of car to permit the egress of passengers in the event of an accident.

The car is to have a maple floor $1\frac{1}{4}$ inches thick, provided with rubber tiling, with rubber or copper interlocking pieces. Rubber tiling to be square, not less than $\frac{3}{8}$-inch thick. The pattern desired is a large and a small square, large square to be red and small square green. No geometrical border is required. A $\frac{3}{8}$-inch brass strip to be provided along entrance opening of car to make a finish and joint between tiling and edge of car.

The ornamental cage to cost not less than $

Annunciator. An electric annunciator of the needle type, with metal case finished to harmonize with the car, is to be placed in the car. The annunciator is to be connected to a battery and to push buttons at each landing. Annunciator wiring in the hoistway is to be run in iron conduit.

Light fixture. The car is to have an electric fixture of suitable design with two Edison base sockets properly connected by means of all necessary wires, etc., to the electric-wiring system of the building. An outlet for this connection has been provided in hoistway, but this contractor must alter same if necessary so that car can land at either extremity of travel without excess of conducting cable. A flush snap switch is to be mounted in car for control of the electric lights.

Tablet. This contractor will be required to furnish and install near elevator machine a polished blue Vermont marble tablet not less than 1¼ inches thick, or if mounted with controller board of same thickness, having mounted thereon one double-pole, single-break knife switch, and one 0–300 volt, dead-beat, direct current voltmeter and one ammeter of capacity 10 per cent greater than the maximum starting or accelerating current. Both instruments are to be of the D'Arsonval type, enclosed in iron dust-proof cases of design suitable for mounting on the tablet. The scales must be large and plain, that of the voltmeter being such that each division indicates not more than 5 volts.

Bidders must state on proposal sheet the capacity and make of the ammeter proposed to be furnished. Ammeter is to be connected in the circuit by means of a double-pole, double-throw switch in such a manner that the instrument may be entirely cut out of the circuit without the service being interrupted or any change of connections being necessary.

All connections to be made on back of tablet by means of copper lugs, to which motor leads and mains are to be soldered.

Connections. Two-wire power feeders have been run to location shown on drawing under another contract. This contractor must connect them to tablets above specified.

All connections between motor and its controller and between controller and tablet hereinbefore specified must be made by this contractor.

All conductors are to be run in steel conduit, terminating in approved conduit fittings, except such connections between controller and motor as are so short as to be self-supporting, and these must be fully protected from abrasion or other mechanical injury.

Conductors must be rubber-covered, well tinned, soft drawn copper of highest conductivity, made in strict accordance with the National Electrical Code, and must have the distinctive marking of the maker. All conductors No. 8 Brown and Sharpe gauge and larger will be stranded and connections made by soldering wires in cup lugs.

Wiring system must test free from short circuits and grounds, and the insulation resistance between conductors and between conductors and ground must not be less than one megohm.

Where size of conductors is not given the capacity must be such that the maximum current carried will not exceed the limits prescribed by the National Electrical Code.

INSTRUCTIONS RELATIVE TO THE INSPECTION AND TEST OF NEW ELEVATORS

First ascertain if the elevator will lift the specified load at specified speed. To ascertain speed points, mark off in hoistway about 6 feet 0 inch above the bottom landing and about 6 feet 0 inch below top landing Place paper at these points and measure distance between them Then have car started from first floor with speed load, as specified, and with stop watch ascertain time required for car floor to pass the marks set as above noted. This will determine if specified speed-load duty has been fulfilled.

Then place the maximum load on car and take speed as before. The car should lift the maximum load at a speed within 30 per cent of the speed specified in connection with speed-load.

With the maximum load on car, take speed UP and DOWN and see if speed DOWN (with controller in full speed position) exceeds UP speed by more than 15 per cent. If so, the machine is not in compliance with office specifications.

After tests above noted, see that motor temperature is not excessive and that all parts of the machine work smoothly.

Make it a point to have the prospective elevator conductor present at the test and see that he is well instructed in the care, adjustment, and operation of the elevator. Place him in the car and make him cover a mile run with the stops at all landings in both directions. Ride in car and observe if there is any objectionable side or end play in car, or any disagreeable grinding of the guides and counterweights.

During the mile run, observe also the operation of elevator machine and see that motor and bearings are running smooth and cool.

After all these tests have the guide-grip safeties tripped and see that they act promptly and stop car. Also see that a regular operator is instructed in the manner of tripping governor and re-setting safeties.

It is customary to have one drop test of safeties made in the presence of the government's representative at the building. If this has not been done have the representative of the elevator company unshackle the cables and raise car up to about 15 feet above first floor and suspend same with a rope. Have safety device examined and when elevator man is ready have him cut the rope and let the car fall.

The distance traveled by car after rope is cut must not be less than 6 feet 0 inch nor more than 9 feet 0 inch.

In lieu of cutting cables the following test may be used under the following conditions:

Speed tests are practicable only on direct current installations and are made by speeding up the motor through the medium of inserting resistance in series with the shunt field. A hand rheostat of a capacity to carry the current, and connected in series with the shunt field, is employed, starting up the machine with all the resistance in this rheostat cut out. The inspector should immediately proceed to cut in resistance in the shunt field circuit with the ultimate purpose of increasing the motor speed not over 50 per cent at which speed, or at a slightly lower speed the governor should trip and operate the safeties. The inspector should check this increase in motor speed by tachometer held in place by an assistant, and the rate at which the motor is speeded up by cutting in the resistance should be determined somewhat by the rise of the elevator, and, of course, by the rate of increase in motor speed.

A speed test is possible only when wedge clamp safeties are used, when the elevator speed is normally over 100 feet per minute, and when the rise of the car exceeds 30 feet.

After capacity test has been made, test the automatic terminal stop mechanism on the machine by running car at full speed into both limits of travel with controller handle held over to full speed position. Test the limit switches in hatchway by cutting out machine terminal apparatus.

When safety governor is tripped, as before noted, see that the slack cable device has operated properly.

Pay special attention to the terminal stop mechanism, as this and the cables are two of the most important safety features.

Before making speed load test, above noted, connect in circuit the ammeter and voltmeter, and during test for capacity take readings for accelerating and running current. In this test, even with dead-beat instruments, allow 5 per cent kick on first rush of current in computing the starting current in comparison with running current. The accelerating current is not to exceed the running current by more than 35 per cent when direct current is used, and not over 200 per cent when alternating current is used. See whether the voltage fluctuates badly, and, if so, be careful to allow for it in calculations.

See that the elevator accelerates in 5 seconds in making the above test. After test, adjust the controller so that the car will accelerate in 3 seconds if this quicker acceleration does not give a poor start.

After capacity test reduce load gradually until the current required to run car up is same as that required to come down, indicating a balanced condition of car, and note the balancing load in reporting on results.

Instruct custodian to take up the matter of the supply of oil for operating the elevator with the office.

Be sure that the man who will be in charge of the elevator is fully instructed as to oiling machinery; the proper oil to be placed in gear case; use of lubricant on cables; care of commutaor and controller and care and oiling of guide rails.

It must be borne in mind that technical ability of the man in charge of the elevator, and the care and skill of the elevator conductor, are the most important factors of safety in connection with the operation of the machine.

SMALL POWER PLANTS

WITH SPECIAL REFERENCE TO INSTALLATION IN FEDERAL BUILDINGS UNDER CONTROL OF THE TREASURY DEPARTMENT

In determining whether the mechanical equipment of a Federal building should include a power plant for generation of electric current for light and power, the following items require consideration:

The cost of current if supplied by local electric companies.

First cost.

Whether suitable space is available.

Difference in cost of salaries for power plant operation as compared with salaries in connection with operation of a low-pressure heating system.

Increase in total cost of fuel required for the power plant above that required for a low-pressure heating system.

Increase in cost of water used on account of exhaust steam wasted to the atmosphere.

Interest charge on first cost.

Depreciation charge (amortization).

(Interest and depreciation are assumed as 8 per cent of the first cost of the plant.)

In arriving at the cost of the plant the following figures are used:

Single-valve direct-connected simple engines and generators, per kilowatt, in place	$35 00
Single-valve direct-connected compound engines and generators, per kilowatt, in place	45 00
Four-valve direct-connected simple engines and generators, per kilowatt, in place	45 00
Four-valve direct-connected compound engines and generators, per kilowatt, in place	55 00
Water-tube boilers and setting, with breeching and stack, per horse power, in place	30 00
Switchboard and mountings, per panel, in place	300 00
Piping, pumps, feed-water heater, etc., in place, at 20 per cent of the cost of the boilers, engines, and generators	

The estimated cost of labor for operation is generally the most imporant factor in determining whether a plant shall be installed. For operation of the average small plant in a Federal building the following force will usually be found sufficient:

One chief engineer, at $1,600 per annum.

Three assistant engineers, at $1,200 per annum.
One engineer's helper, at $1,000 per annum.
Three firemen, at $2.50 per day.
Two coal passers, at $2.00 per day.
One fireman helper at $2.25 per day.

In the same building with no electric generating plant and with electric elevators the following force will usually be found sufficient:

One chief engineer, at $1,400 per annum.
Two assistant engineers, at $1,000 per annum.
Three firemen, at $2.25 per day, for seven months in the year.
One fireman helper, at $2.00 per day for twelve months in the year.
Two coal passers, at $2.00 per day for seven months in the year.

To approximate the amount of coal required to heat the building, ascertain the amount of radiation, both direct and indirect, reducing the latter to the equivalent of direct radiation by multiplying it by 3 if a fan is used with the system, or by $1\frac{1}{2}$ if the circulation of air is by natural means. Assume that each square foot of direct radiation or its equivalent will condense 500 pounds of steam in a season of 200 days, and that when boilers are operated for heating only there will be evaporated 7 pounds of water per pound of coal. If only the cubic contents of the building are known, a fair average for buildings in the latitude of New York City will be 1 square foot of radiation per 100 cubic feet of the contents.

To approximate the additional amount of coal required to operate a generating plant, ascertain the size of the generating units as hereinafter described, and assume that the large unit will operate under a fluctuating load varying from $\frac{1}{2}$ to $1\frac{1}{4}$ load 16 hours a day for 165 days, and that the small unit will operate under the conditions noted above 8 hours a day. The steam consumption per indicated horse-power of the engines under the varying loads is taken from the tables hereinafter given, and the total steam consumption in pounds for the two units is reduced to pounds of coal on the assumption that 8 pounds of water will be evaporated per pound of good bituminous coal.

General arrangement of the apparatus. In connection with electric generating plants in Federal buildings, all-steel water tube boilers are installed, if possible, and are designed for a safe working pressure of 150 pounds per square inch, the usual operating pressure being 125 pounds per square inch.

The size of the boiler plant is generally governed by the heating and ventilating requirements, as same are heavier in practically all parts of the country than are the requirements of power for operating the engines. A close approximation of the boiler requirements for direct heating is made by allowing one boiler horse-power for each 7,000 cubic feet of contents of the building.

In event the heating and ventilating requirements and space conditions are not the governing factors in determining the number and size of the boilers, the day load and evening load on the generating plant are determined by the method hereinafter described; and the day load plus the evening load divided by 2 will give the size of the boiler units from which the best results will be obtained, one boiler being sufficient to carry the full load, with some margin, on the daylight run, and the evening load by slightly forcing the fires. This can easily be done by cleaning the fires toward the end of the daylight run and working up a strong deep fire for the commencement of the evening load. Three boilers of the size above noted would generally be installed.

The minimum size of water-tube boiler installed is 100 H.P.

The clear heights which must be allowed from bottom of pit to underside of ceiling beams to insure a proper installation for the water-tube boilers used by the office are as follows:

	Feet	Inches
For boilers of 100 to 150 H.P.	14	6
For boilers of 150 to 175 H.P.	15	0
For boilers of 175 to 200 H.P.	15	6

These boilers are based on 10 square feet of water heating surfaces per horse-power, and are always equipped with some kind of smoke-preventing apparatus.

The boilers are arranged, when possible, to give a short, direct connection to the stack, and are so located as to be close to the engine room and convenient to the coal and ash rooms.

A firing pit (especially a deep one) is always a detriment and is avoided if possible.

The boiler and engine rooms are ventilated by drawing the hot air away from the ceiling by a fan or by fans, and allowing the cold air to flow in by gravity through doors and windows so arranged that firemen will not be subjected to a cold draft.

The location of the engine room either directly in front or directly at the rear of the boiler room gives the shortest pipe connections, and hence the least friction and condensation in the steam mains.

This arrangement of engine and boiler rooms also allows for increase in the boiler, engine, and switchboard capacity by lateral extension, giving at all times a neat and compact arrangement of apparatus, and one which is economical both in first cost and in operation.

Arranging the engines with cylinders on center lines parallel with center lines of boilers, and close to partition between boiler and engine room (5 to 10 feet clearance between wall and cylinder head) further shortens steam and exhaust connections.

Size and number of generating units. The full connected lighting and power load is ascertained, special attention being given to accurate determination of the *rated* horse-power of all elevator motors, as this item has an important part in determining the size of the units. The starting current of elevators is never less than 35 per cent in excess of the maximum running current with direct-current motors, and rises to 200 per cent with alternating-current motors.

Federal buildings in which generating plants are installed are all 24-hour buildings, and no breakdown connection is made with the local lighting companies; therefore the plants are made larger than in commercial practice, and never less than three units are installed; generally two large units, each sufficient to carry the peak load, and one small unit to carry the after-midnight load.

Usually, with a view to insuring as far as practicable continuous operation, a four-unit plant is selected, comprising two large units, each able to carry the peak load, and two small units, each capable of carrying the after-midnight load.

No unit smaller than 75 kilowatts, and generally none larger than 150 kilowatts is installed. The reason for not using a unit smaller than 75 kilowatts where an intermittent power load prevails needs no explanation, while space conditions, etc., generally forbid the installation of units exceeding 150 kilowatts.

To determine accurately the proper number and size of units within the limits stated, further analysis is made, as follows:

Constant load, consisting of.....	a percentage of the total number of lights connected. a constant power load consisting of certain motors likely to be run continuously.
Intermittent load, consisting of.	electric elevators, motors for mail lift, ventilating fans, house pump air compressors, circulating pumps (if used), vacuum cleaning machine, automatic temperature-control apparatus, air washer-motors.

In determining the size of the units, the power demand should be analyzed under "day load" and "night load" conditions. With the post office operating all night the heaviest demand for current will be between the hours of 4 p.m. and 10 p.m., while from 11 p. m. to 6 a.m. the demand will be the smallest.

The day load will consist of a small lighting load plus a constant power load plus an intermittent power load, all of which may be determined approximately, as follows:

- Day load....
  - Lighting......
    - 30 per cent of basement lights.
    - 20 per cent of post-office workroom lights.
    - 10 per cent of first-floor corridor lights.
    - 5 per cent of office lights on all floors.
  - Power...
    - Constant..
      - ventilating fan motors.
      - circulating pump motor for air washer.
    - Intermittent..
      - electric elevators.
      - house pump.
      - mail hoist motor.
      - air compressor.
      - vacuum cleaning motor, etc.

The constant power load can be accurately determined, as it should not be difficult to decide definitely what ventilating fans, pump motors, etc., will be operated more or less continuously.

After the day-load conditions have been thoroughly investigated the load conditions of the evening and after-midnight runs should be determined, as follows:

- Evening load..........
  - 70 per cent of all post-office workroom lights.
  - 30 per cent of all basement lights.
  - 60 per cent of first floor corridor lights.
  - small power load for fan, pump, or similar service, determined from the plans.
- After-midnight load...
  - 40 per cent of all post-office workroom lights.
  - 30 per cent of all basement lights.
  - 30 per cent of all first-floor corridor lights.
  - small power load to be determined from the plans.

If the day load plus the after-midnight load is equal to or greater than the maximum or evening load, one unit should be selected with full-load rating equal to the day load, and one unit with full-load rating equal to the after-midnight load. These two units can then be operated in parallel to carry the maximum or evening load.

The capacity of the spare unit is made equal to the day load.

If, however, the maximum load is greater than the sum of the day and after-midnight loads, the size of the smaller unit must be equal to the difference between the day load and the maximum or evening load.

As hereinafter stated, the large units must never be less in capacity than four times the rated kilowatt capacity of all elevator motors which may be in use at one time.

When the day load is larger than 150 kilowatt, two or more units, preferably of equal capacity, are chosen.

To illustrate the method of proportioning units:

Assume that the constant light and power day load is 110 kilowatts, and that two electric elevators are intermittently in use, each having a motor rated at 10 kilowatts, and each motor requiring 15 kilowatts to start. The maximum instantaneous load possible under the conditions is 110 plus 15 plus 15, or a total of 140 kilowatts.

A 125-kilowatt unit would be selected for this case, as said machine has an overload capacity of 156 kilowatts for two hours. The generator could easily take care of a vacuum-cleaner or other small motor in addition to the load stated.

For another example; assume that the constant light and power day load is 50 kilowatts, and that there are two electric elevators in service, each having a motor rated at 10 kilowatts and requiring a starting current of 15 kilowatts for each motor, or a total of 30 kilowatts intermittent load. A 75-kilowatt generator would be selected for this service.

In selecting the size of a generating unit which must carry the constant power and light day load and also an elevator load, the size of the generator should never be less than four times the *rated* kilowatts of all the electric elevators which may be in use. The relation of the generator capacity to the intermittent elevator load must not be overlooked or the voltage regulation will be poor and the lights will blink when the elevators start.

In commercial practice the generator capacity is, under adverse conditions, sometimes made only 2½ times the rated kilowatt capacity of the elevator motors, but the results are bad.

The foregoing methods of determining the generating unit capacity are for buildings where the larger unit will not exceed 150 kilowatts. When conditions arise which require the design of a plant involving much larger capacities, and where perhaps from four to ten elevators are in daily use, it is advantageous to provide and operate two units in parallel for the day load in lieu of one; or one large one and three of one-half its capacity sometimes will prove a better arrangement, depending on the relative proportion of the constant and intermittent loads, etc.

No hard and fast lines can be laid down to govern the size of generating units, but the procedure is substantially as stated.

TYPE OF ENGINES

By reason of the advancement in steam engineering in recent years, a number of types of steam engines suitable for operating electric generators are available, each type possessing some merit peculiar to itself which adapts it to fill to best advantage certain operating conditions.

The simple and compound high-speed single-valve, and simple and compound medium-speed Corliss-valve engines are the principal types offered. These engines are inclosed, self-oiling, and equipped with automatic shaft governor. They are built either horizontal or vertical and are arranged for direct connection to an electric generator.

No arbitrary rules can be laid down to determine the choice of the proper type of engine, and each particular installation requires individual consideration. Floor space, size of unit, cost of coal, characteristics of load, steam pressures, building heating requirements, and initial cost of installation are the principal factors which govern such selection.

Simple single-valve engine. This type has the fewest mechanical parts of any of the types mentioned, which commends it in all cases where a minimum of attention is desired and attendants of only average ability are employed. It is also the least expensive, which further commends it where first cost is a factor. On the ground of relatively smaller investment and depreciation, it is usually selected for small units ranging up to and including 50 kilowatts capacity, as in these sizes the saving of other types in steam does not offset the fixed charges. This type is also recommended in somewhat larger sizes where coal is not expensive (say $2.00 or less per ton), and for installations where the unit is in service for but short periods. It is also well adapted for use in buildings which must be heated during a large part of the year, or where the demand for steam heating exceeds in amount the engine exhaust.

The speed of this type of engine range as follows:

Size kilowatt capacity	Revolutions per minute
25	300-450
35	300-350
50	275-325
75	250-325
100	250-300
125	225-275
150	200-260
200	150-225
250	150-220
300	150-200

The steam consumption per *indicated* horse-power per hour for all the different sizes given above should not exceed the following amounts when operating with atmospheric exhaust and at the initial steam pressures stated:

I. S. P.	Quarter load	Half load	Three-quarter load	Full load	One and one-quarter load
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
80	48.9	37.8	34.3	33.8	34.3
90	44.0	35.4	32.4	32.0	32.5
100	40.5	33.4	30.9	30.6	31.1
110	37.6	31.7	29.6	29.2	29.7
120	35.3	30.2	28.5	28.1	28.4
130	33.9	29.0	27.6	27.2	27.7
140	32.5	28.1	26.2	26.3	26.9
150	31.6	27.1	25.8	25.6	26.1

The mechanical efficiency of engines of this type is usually not less than 95 per cent for engines under 300 H.P. capacity and 94 per cent for larger sizes.

Simple Corliss-valve engine. This type is a development of the releasing Corliss-valve gear engine and partakes of its characteristics so far as steam consumption is concerned. By reason of fewer parts, without auxiliary cut-offs, dash-pots, etc., more advantageous regulation and speeds are obtainable, making it admirably suited for installation in Federal buildings, where the available floor space is usually limited. It is recommended for units 75 kilowatts in capacity and above, for localities where coal costs over $2.00 per ton, and with steam pressures in general use which range from 110 to 125 pounds.

The steam consumption curve of engines of this type is very flat throughout its range, which adapts it for installations with fluctuating loads. This, combined with the high mechanical efficiency, commends this type for the usual Federal building installation.

The usual speeds of Corliss-valve engines are about as follows:

Size kilowatt capacity	Revolutions per minute
75	225–250
100	225–250
125	200–225
150	200–225
200	150–200
250	150–200
300	150–200

Steam per *indicated* horse-power per hour required by engines of this type when operating at the initial steam pressures stated and with atmospheric exhaust should not exceed the following amounts for any of the sizes above noted:

I. S. P.	Quarter load	Half load	Three-quarter load	Full load	One and one-quarter load
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
80	40.0	29.6	27.4	27.5	28.8
90	37.0	27.8	26.1	26.4	27.5
100	34.8	26.4	24.8	25.3	26.4
110	33.3	25.3	23.8	24.3	25.3
120	32.4	24.5	23.1	23.6	24.7
130	31.8	24.0	22.6	23.0	24.2
140	31.2	23.6	22.2	22.6	23.8
150	30.4	23.1	21.8	22.3	23.5

The mechanical efficiency of simple Corliss-valve engines is usually not less than 94 per cent for engines under 300 H.P. and 93 per cent for larger sizes.

Compound single-valve engine. This engine is adapted for installations having comparatively high steam pressures ranging upwards from 120 pounds with no back pressure, or operating condensing. As shown by the table of steam consumption following, compound engines are not economical at light loads, and therefore constant approximate full loads are necessary for best results.

The speeds of this type, which are built either tandem or cross-compound, are about the same as given for the simple single-valve engines.

The steam consumption per *indicated* horse-power per hour for engines ranging from 75 to 300 kilowatts should not exceed the amounts given in the following table when operating at the initial steam pressures given and with atmospheric exhaust:

I. S. P.	Quarter load	Half load	Three-quarter load	Full load	One and one-quarter load
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
100	48.6	32.9	28.2	27.5	28.0
110	44.6	29.5	25.4	24.6	25.0
120	42.4	28.2	24.3	23.5	24.0
130	41.3	27.6	23.7	23.0	23.4
140	40.3	27.0	23.2	22.5	22.9
150	39.4	26.5	22.7	22.0	22.4
160	38.7	26.0	22.2	21.5	21.9
170	38.3	25.6	21.8	21.1	21.6

The amounts given in the preceding table are bettered approximately 15 per cent for the quarter and half loads and 20 per cent for the other loads when operating condensing with about 24 inches of vacuum;

the amount of steam required for the condenser, when condensing water is available, will average 7 per cent of the steam used by the engine, leaving a net gain of about 8 per cent for light loads and 13 per cent for heavier loads when operating condensing instead of with atmospheric exhaust.

For engines of this type of less than 300 H.P. capacity, the mechanical efficiency is about 93 per cent, and in larger sizes about 92 per cent.

Compound Corliss-valve engine. This type of engine is recommended where proper operating conditions prevail and extreme economy is desired. These conditions are steam pressures of 120 pounds or higher, comparatively steady full load, and exhausting with little or no back pressure, or operating condensing.

The speeds at which engines of this type operate are about the same as given for simple Corliss-valve engines.

The engines of this type ranging in size from 75 to 300 kilowatts, when operating at the initial steam pressures given and with atmospheric exhaust, should not consume at varying loads more than the amounts per *indicated* horse-power per hour following:

I. S. P.	Quarter load	Half load	Three-quarter load	Full load	One and one-quarter load
Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
100	47.0	32.3	26.7	25.2	24.9
110	43.4	30.0	24.3	22.6	22.7
120	41.2	28.0	22.5	21.1	21.3
130	39.6	26.8	21.3	19.8	20.3
140	39.0	26.4	20.9	19.4	19.9
150	38.5	26.0	20.5	19.0	19.5
160	38.0	25.5	20.1	18.7	19.1
170	37.6	25.0	19.8	18.4	18.8

The amounts given in the table above are improved about the same percentage when operating condensing as given under compound single-valve engines preceding.

The mechanical efficiency of compound Corliss-valve engines of less than 300 H.P. capacity is usually not less than 92 per cent, and for larger sizes 91 per cent.

Selecting an engine. To show the utility of the foregoing data, the following example is given for determining the proper engine to be selected under assumed conditions of operation:

The engine is to be required to drive a 100-kilowatt generator with 110 pounds initial steam pressure, exhausting at atmospheric pressure; loads ranging between one-half and one and one-quarter full loads; unit operating ten hours per day, 300 days per year, with coal costing $3.50 per ton.

With a simple single-valve type the steam consumption for varying loads taken from the table is as follows:

	One-half load	Three-quarter load	Full load	One and one-quarter load
	Pounds	*Pounds*	*Pounds*	*Pounds*
Steam consumption per I.H.P. per hour	31.7	29.6	29.2	29.7

The steam required per hour at varying loads would be as follows:

One-half load—31.7 lbs. × 75 I.H.P. = 2,375 lbs.
Three-quarter load—29.6 lbs. × 112.5 I.H.P. = 3,340 lbs.
Full load—29.2 lbs. × 150 I.H.P. = 4,370 lbs.
One and one-quarter load—29.7. lbs × 187.5 I.H.P. = 5,575 lbs.

4)15,660 lbs.

Average steam per hour.......................3,915 lbs. × 3,000 hours = 11,745,000 lbs., the total steam required for the engine per year.

With the simple Corliss-valve engine operating the same as above, with steam consumption taken from the table, steam required per hour would be in accordance with the following:

	One-half load	Three-quarter load	Full load	One and one-quarter load
	Pounds	*Pounds*	*Pounds*	*Pounds*
Steam consumption per I.H.P. per hour	25.3	23.8	24.3	25.3

One-half load—25.3 lbs. × 75 I.H.P. = 1,900 lbs.
Three-quarter load—23.8 lbs. × 112.5 I.H.P. = 2,680 lbs.
Full load—24.3 lbs. × 150 I.H.P. = 3,650 lbs.
One and one-quarter load—25.3 lbs. × 187.5 I.H.P. = 4,810 lbs.

4)18,040 lbs.

Average steam per hour.......................3,260 lbs. × 3,000 hours per year = 9,780,000 lbs. yearly steam consumption.

A compound single-valve engine operating under the same conditions will for varying loads require the following amounts of steam:

	One-half load	Three-quarter load	Full load	One and one-quarter load
	Pounds	*Pounds*	*Pounds*	*Pounds*
Steam consumption per I. H. P. per hour	29.5	25.4	24.6	25.0

One-half load—29.5 lbs. × 75 I.H.P. = 2,210 lbs.
Three-quarter load—25.4 lbs. × 112.5 I.H.P. = 2,860 lbs.
Full load—24.6 lbs. × 150 I.H.P. = 3,680 lbs.
One and one-quarter load—25.0 lbs. × 187.5 I.H.P. = 4,730 lbs.
4)13,480 lbs.

Average steam per hour..........................3,370 lbs. × 3,000 hours=10,110,000 lbs. steam per year.

With a compound Corliss-valve engine the steam required at varying loads will be as follows:

	One-half load	Three-quarter load	Full load	One and one-quarter load
	Pounds	*Pounds*	*Pounds*	*Pounds*
Steam consumption per I. H. P. per hour..............................	30.0	24.3	22.6	22.7

One-half load—30.0 lbs. × 75 I.H.P. = 2,250 lbs.
Three-quarter load—24.3 lbs. × 112.5 I.H.P. = 2,740 lbs.
Full load—22.6 lbs. × 150 I.H.P. = 3,380 lbs.
One and one-quarter load—22.7 lbs. × 187.5 I.H.P. = 4,290 lbs.
4)12,660 lbs.

Average steam per hour..........................3,165 lbs. × 3,000 hours = 9,495,000 lbs. yearly steam consumption.

Comparing the performance of the simple single-valve engine with the simple Corliss-valve engine, there will be the difference between 11,745,000 pounds steam and 9,780,000 pounds, or 1,965,000 pounds steam less required for the simple Corliss-valve than for the simple single-valve engine. Reducing this saving in steam to coal at 8 pounds evaporation, there is a total saving of 245,625 pounds of coal, or about 109 tons of 2,240 pounds each. This saving in coal at $3.50 a ton amounts to approximately $381.00 per annum, which would justify the difference in the amount of investment in the two engines, roughly about $1,200.

While the compound single-valve engine shows a gain over the simple single-valve engine, it is obviously insufficient to weigh against the selection of the simple Corliss-valve type; and as the compound Corliss-valve engine, in comparison with the simple Corliss-valve type, does not show enough gain to warrant selection at its greatly increased price, it may be concluded that the simple Corliss-valve engine would be the proper one to choose under the assumed conditions.

If the coal in the above example had been purchased for $1.50 per ton, the yearly saving with the simple Corliss-valve engine over the simple single-valve engine would have been only $163.00, an amount insufficient to justify the expenditure of the additional sum necessary to purchase the simple Corliss-valve engine.

The engine efficiencies have been ignored in the above calculations, as the only object was to show the use of the tables and the method of calculating the steam required per indicated horse-power with different type machines.

ELECTRIC GENERATORS

The usual load consists of elevators, lighting, ventilating fans, and pumps, the elevator load being the major part of the total load. It is therefore desirable to use a generator of such characteristics that a fairly constant lighting voltage will be maintained when the elevators are thrown on the circuit, and frequent overloads will be carried without sparking.

These characteristics are best obtained in the interpole design.

In a non-interpole generator, sparking is due primarily to a local magnetic field surrounding a coil which is being commutated. This field sets up a counter-electromotive force, or voltage, in the commutated coil in such a way as to oppose the reversal of the current in the coil, and thus tends to cause sparking as the coil or commutator bar leaves the brush. This action increases with current or load, and is especially destructive at heavy overloads.

In a non-interpole machine, sparkless commutation may be obtained if the brushes can be so located that the armature coils, short circuited by them, are brought into a magnetic field of exactly the right direction and strength to neutralize the effect of the local field at the moment of commutation.

Such a field is found to exist near the tips of the pole pieces, and it has been customary to advance the generator brushes sufficiently to bring the armature coils within it during commutation; but this field varies in strength under various conditions of loads, and instead of becomming stronger as desired with increase of loads, it actually becomes weaker.

Interpole generators. In interpole generators the proper conditions for commutation are obtained by the use of small poles interspaced between the main poles.

The interpoles have their windings in series with the armature and set up magnetic fields which annul the effect of the fields formed by armature magnetization, and generate in the commutated coils an electromotive force which assists the reversal of the current. Since the interpole coils are in series with the armature, the interpole field strength varies in proportion to the load, and it thus has the proper corrective effect at all loads.

Since the electromotove force due to the interpole which assists reversal has a definite position under the interpole, the coil being reversed must also be located accurately with respect to this reversing electromotive force. The brushes are consequently located on the true neutral point, and experience proves that sparkless commutation can be obtained under practically all conditions from no-load to very heavy overloads.

Commercial kilowatt and speed ratings of direct-current generators. Standard commercial speeds and kilowatt capacities from 25 kilowatts to 300 kilowatts for 125-volt, 250-volt, and 125–250-volt 3-wire generators are as follows for interpole machinery:

Kilowatt	R.P.M.
25	295–305–310–325
35	285–305–315
50	275–280–290–300
75	250–265–275–290
100	250–260–275
125	225–250–260–275
150	200–220–250–260–275
200	100–150–200–210–220
250	150–200–220
300	100–120–150–200–220

Late designs are provided with steel frames to produce rugged and stiff construction and at the same time to reduce the handling and shipping weights and permit light foundations.

Ventilation. The later types of machines have open-end windings on the armatures as well as air ducts in the armature cores. The shunt field coils are form-wound in comparatively long coils of small radial depth. The series and interpole coils are wound from bare copper strap insulated with spacers, with ample air ducts between the poles, shunt coils, and series coils, so that the armature and field windings of the generator are open to free ventilation.

Temperature rise and overloads. Based on a room temperature of 25° C. the temperature rise at full load should not exceed 35° C. after continuous operation, nor 50° C. after two hours' operation at 25 per cent overload. A small margin should be allowed, say 5° C., on the commutators of 125-volt generators.

SPECIFICATION

The following is a specification for engines and generators as prepared in the office of the Supervising Architect:

ENGINES

Type. The engines are to be of the single-cylinder, automatic, horizontal, side-crank type with gravity feed lubrication, and are to be designed to operate non-condensing on dry saturated steam at 110 pounds gauge pressure at the throttle; the speed of the 100-kilowatt generator engine to be between 225 and 250 revolutions per minute, and that of the 50-kilowatt generator engine to be between 275 and 300 revolutions per minute.

Capacities. The engines are to be designed so as to operate most economically when generators are delivering three-quarter load at the rated voltage and speed, and shall be capable of operating the generators for two hours when delivering 25 per cent overload at rated voltage.

Foundations. Foundations to be of the required form to suit engine and generator sub-bases, and to be constructed of 1:2:3 concrete with the bottom not less than 4 feet below the floor line The top must extend not less than 6 inches beyond the edge of sub-base frames all around, and the batter in the depth specified must be not less than $3\frac{1}{2}$ feet each side. Concrete foundation to be provided with cushion of 6-inch deep sand. Foundation bolts to be provided with washers and wrought-iron sleeves.

Sub-bases. Each engine to be provided with a heavy and substantial cast-iron sub-base upon which shall be mounted the engine; the sub-base of the 100-kilowatt generator engine to be extended under cylinder for support of cylinder.

The sub-base of generators must be secured to engine sub-base with suitable bolts and dowels, and both sub-bases secured to the foundations.

Frames. Each engine to be provided with a heavy and substantial cast-iron frame designed for strength, rigidity, and compactness, and to be provided with suitable covers to prevent throwing oil and allowing dust to come in contact with the moving parts.

Bearings. Each engine to have two bearings; one to be set in the engine frame and the other to be outboard beyond the generator. Bearings shall be long, well-proportioned, and dust proof. The outboard bearing to be of the oil ring type. Bearings to be lined with genuine babbitt metal carefully peened in place and accurately bored to gauge. The bearings to be provided with large size oil wells, visual gauges, and petcocks for drawing the oil. Bearings to be provided with means for adjustment.

Lubricating system. Each engine to be provided with an automatic self-lubricating system which shall supply pure, clean oil continuously to all bearings, etc., the operation of system to be positive and free from throwing or spilling the oil, and arranged to reuse the oil.

Cylinders. Each cylinder to be made of best grade of close-grained cast iron, bored true and smooth, and of sufficient thickness to allow for reboring. The cylinder to be well lagged with magnesia or other material having equal heat insulating value, and covered with ornamental cast-iron jackets or with Russia iron, properly secured to the cylinder casting.

Pistons. The piston heads shall be hollow cast iron, with at least two snap rings with lap joints, made from first quality of hard, close-grain cast-iron sprung into accurately fitting grooves. Rings shall override the bore of cylinder. Piston rods to be best quality nickel steel. Rods to be turned to a taper at the piston ends and each driven up to a shoulder and securely held by a heavy nut to be drilled and provided with cotter pin. The forward ends to be screwed into crossheads and provided with jam nut to prevent turning.

Crossheads. The crossheads to be made of cast iron or steel, and be provided with adjustable bronze shoes circular in form. Crosshead pin to be made of steel hardened and ground and held in place by taper fit and nut.

Connecting rods. The connecting rods to be forged open-hearth steel in one piece with solid end and crosshead end. The crosshead boxes to be made of phosphor-bronze adjustable by means of wedge. Crank ends to be fitted with boxes of steel lined with genuine babbitt metal peened and bored to fit the pins.

Crank shafts. Crank shafts to be constructed of open-hearth steel forged in one piece, with counterbalancing crank disks of annealed steel, securely fastened thereon.

Valves. The valve for the 50-kilowatt generator engine to be perfectly balanced, of the adjustable type, constructed of best quality hard close-grain cast iron, operated in removable bushings or pressure plates.

The 100-kilowatt generator engine to be fitted with four valves of the semirotary or gridiron type, designed to be slightly unbalanced and securing positive steam-tight seating over the admission ports. Steam valves to be of the multiported type giving ample port openings for all points of cut-off. Exhaust valves to be designed to give ample port area and insure tightness. All valves to be constructed of best quality hard close-grain cast iron. Semirotary steam valves to be provided with removable bushings or cages; gridiron valves to be provided with suitable balancing plate.

Valve mechanism. The valve mechanism on each engine to be designed to give quick and positive motion to the valves in opening and closing. All pins subject to wear to be made of steel hardened and ground. All boxes for pins to be be made of phosphor-bronze and to be adjustable without filing. Lubrication of pins and bearings to be accomplished while in motion by compression grease cups placed at accessible points or to operate in oil wells.

Eccentrics. The eccentrics to be strong and light to reduce the strain upon the governor springs, and hung on hardened steel pins operating in removable bronze bushings. The eccentric straps to be lined with best quality of antifriction metal. Ample means of lubrication to be provided and designed to be free from oil throwing when in motion.

Governors. Each engine to be equipped with a centrally balanced centrifugal inertia governor which will maintain a perfect condition of balance in all positions of cut-off, and operate with equal ease and isochronism from zero to 62.5 per cent cut-off.

The governor pins and bushings to be made of steel and bronze, the former hardened and ground true. The lever-arm bearing to be of the antifriction type.

Steam consumption. Each bidder must state in proposal sheet the indicated horsepower, full load of each engine, and the maximum steam consumption when operating under conditions herein specified at uniform varying loads, which will receive consideration in award of contract.

Each engine when operated under conditions herein specified and at uniform varying loads must not consume more than the amount of dry steam in pounds per indicated horsepower per hour, determined by the weight of condensed exhaust steam, for each load as stated below:

	Load				
	25 per cent	50 per cent	75 per cent	100 per cent	125 per cent
50-kilowatt generator engine, dry steam..	37.6	31.7	29.6	29.2	29.7
100-kilowatt generator engine, dry steam..	33.3	25.3	23.8	24.1	25.7

Shop test of engines. The efficiency, capacity, etc., of each engine to be determined by actual test in the presence of the Department's authorized agent, who shall determine the test conditions.

The tests are to be made at the shop where engines are constructed, and are to begin within ten days after receipt of notice from the contractors of their readiness to commence tests, and to be at the expense of the contractors, except traveling and other expenses of the Department's agent.

Engines to be run at one-half, three-quarters, full, and one and one-quarter loads for one hour under each load, during which time the exhaust steam will be condensed and weighed, and indicator cards taken every five minutes.

Engines to be run at the speeds specified with steam at 110 pounds pressure per square inch at the throttle, quality of which will be determined by throttling calorimeter placed in steam pipe above throttle.

Under above conditions the friction load must not exceed 5 per cent of the normal capacity of engine for the 50-kilowatt generator engine, and must not exceed 7 per cent for the 100-kilowatt generator engine.

It must be distinctly understood as one of the conditions under which bids are submitted for the work embraced in this specification that the engines must meet every requirement of the tests above specified, under which conditions the contract price will be paid. In the event the engines fail to meet the requirements for steam consumption or friction load, or both, the Department shall have the right to reject the engines absolutely and require the supply of satisfactory engines which comply with the specification requirements in regard thereto; or, if the Department elects to accept the engines, the contract price shall be the amount named in the contract for a satisfactory plant, less the amount of deficiencies shown by tests above described upon the following basis:

Nine hundred dollars per pound or proportional part of said $900 for each fraction of a pound below the guaranteed efficiency for the 50-kilowatt generator engine, and $1,800 per pound or proportional part of said $1,800 for each fraction of a pound below the guaranteed efficiency for the 100-kilowatt generator engine, based on any or all of the varying loads, irrespective of economy at other loads.

Two hundred and fifty dollars for each per cent or proportional part of said $250 for each fraction of a per cent above the specified friction load for the 50-kilowatt generator engine, and $500 for each per cent or proportional part of said $500 for each fraction of a per cent above the specified friction load for the 100-kilowatt generator engine.

The Supervising Architect reserves the right to waive these tests or any portion thereof and to require contractor to submit certified test sheets, in triplicate, for approval, it being understood that those portions not waived shall be exacted when apparatus is installed if not performed at shop as specified above.

Regulation. After engines are installed in position they must be adjusted to run smoothly and practically noiselessly. They must be tested at shops for regulation, which tests must show that slow change from no load to full load and vice versa will not produce more than $1\frac{1}{2}$ per cent speed variation, and from full load suddenly thrown on or off the speed variation shall not be over 2 per cent.

Fittings. Each engine to be furnished with the following fittings:

One throttle valve.

Automatic cylinder relief and drain valves.

Mechanical cylinder lubricator, piping, etc.

Auxiliary hand oil pump.

Steam chest drain connections with valves.

Indicator piping with three-way cocks and angle globe valves.

Attached indicator reducing motion.

Set of adjusting wrenches on hardwood board.

All necessary drip, drain, and indicator piping, which must be brass, nickel plated, exposed above floor.

GENERATORS

Type. Generators are to be direct-connected, engine-driven, interpole type for 125-volt direct current, each mounted on sub-base, connected to its engine sub-base. One to have full-load rating of 50 kilowatts and one to have full-load rating of 100 kilowatts at the speeds determined by the full load speeds of engines which must be between the limits previously stated. Consideration will be given to proposals based on generators without interpole feature.

The armatures and commutators to be built upon ventilated sleeves or spiders, arranged to be pressed on and keyed to shafts.

The field or magnet frames to be provided with screws and liners for adjustment in position.

Frames. The frames of generators to be made of a high-grade cast steel or of cast iron of high permeability, sound and free from blowholes, The seats for the pole pieces to be accurately finished; seats for the bolt heads and nuts to be faced.

Poles. The poles to be made of laminated steel or iron, bolted to the frames. The interpoles to be of steel, bolted to the frames.

Field coils. The main field coils to be form wound, provided with ventilating ducts, and be so secured that they may be readily removed without unwinding; to be so proportioned as to automatically give the voltages specified under "Regulation;" and be properly insulated in a substantial manner with material of the best quality and thoroughly tested.

Armatures. The armatures to have slotted cores. The windings to be thoroughly insulated, provided with ventilating ducts for cooling the windings, and coils to be securely held in place. The armatures must be balanced both mechanically and electrically.

Commutators. Commutator segments to be of drop-forged or hard-drawn copper of highest conductivity, insulated with mica of even thickness and proper hardness to insure uniform wear, and must run free from sparking or flashing at the brushes at any load or during change of load. They must have ample bearing surface and radial depth for wear.

Brushes. Brushes to be of carbon, of such size and number as will carry all the loads covered by this specification without injurious heating.

With the fixed position of the brushes, there is to be practically no sparking or burning of the brushes or blackening of the commutator within the limits of the time loads specified, nor any injurious sparking at the momentary overloads specified.

Brush holders. The brush holders to be so constructed that the tension on any brush may be adjusted without lifting the brush from the commutator and without the use of any tools; and that any brush can be removed while the machine is in operation without disturbing the others and without moving the holder on the stud. Flexible connections to the brushes to be used to prevent injurious current in parts of brush-holder mechanism.

The brush holders to be mounted on studs extending from suitable yokes or rings, which must be supported from the frames.

Regulation. The voltage regulation to be 110 volts no load to 117 volts full load based on a variation of speed in the engine of not more than 2 per cent from no load to full load.

Insulation. The frames of machine must have an insulation resistance from the field coils, armature windings, and brushes of not less than 1 megohm. Generators to be capable of standing a breakdown test of 1,500 volts alternating current for one minute.

Heating effect. Generators are to be run continuously at full rated load until all parts have reached a constant temperature and for one hour thereafter, at which time the temperature rise of the arma tures and field coils shall not exceed 35° C. and of the commutator 40° C. above the surrounding air, corrected to 25° C.

Immediately following the full-load run, and starting with temperatures not less than the final temperatures of full-load run, each machine shall be operated for two hours at 25 per cent over-load, at the expiration of which time the temperature rise of the armature and field coils shall not exceed 50° C. and of the commutator 55° C. above the surrounding air, corrected to 25° C.

Efficiencies. The efficiencies of generators must not be less than the following:

Load	100-kilowatts	50-kilowatts
One-half	88.5	88.0
Three-quarters	89.0	88.0
Full	88.5	87.5
One and one-quarter	87.5	86.0

Shop test of generators. The efficiency, heating effect, insulation resistance, etc., of generators shall be determined by actual test in the presence of the Department's authorized agent, who shall determine the test conditions.

The test to be made at the shop where generators are constructed, and to begin within ten days after receipt of notice from contractors of their readiness to commence test, and to be at the expense of contractors, except traveling and other necessary expenses of the Department's agent.

The Supervising Architect reserves the right to waive these tests or any portion thereof and to require contractors to submit certified test sheets in triplicate for approval, it being understood that those portions not waived shall be exacted when apparatus is installed, if not performed at the shop as indicated above.

THREE-WIRE GENERATORS

In all new plants, and in all old plants in which the motor equipment and the generator sets are to be entirely replaced and the building rewired, the practice of the office now is to install a 3-wire system and use 3-wire generators.

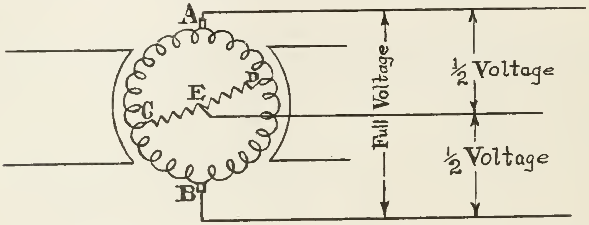
The 3-wire system allows a saving of 25 per cent of the weight of copper in the feeders, when figures are on the basis of current capacity, and a saving of 62½ per cent when figured on a basis of drop in potential; the neutral wire being considered as equal in size to one of the outside wires. The 3-wire system admits of using 110 volts for the lighting system, which is the most desirable voltage, and 220 volts for motors, which is the most desirable from a standpoint of first cost and general operating conditions. The half voltage obtainable from either side of the system is also desirable for variable-speed motor work or low voltage lamps.

A 3-wire machine consists of a standard 2-wire machine with the additional described below.

Four slip rings are mounted on the shaft and connected with the armature winding at intervals corresponding to 90 electrical degrees, where 360 electrical degrees is taken as the distance between two poles of the same polarity. The voltage at the slip rings is 2-phase alternating.

The balance coils are connected one to each phase.

Each balance coil has a neutral wire connected to its winding midway between the end. These are connected together and form the neutral of the 3-wire direct current system. One balance coil could be employed but the 2-phase connection has been found to give a better distribution of current in the generator armature and a better voltage regulation.



Balanced voltage. The action of the coils in balancing the voltage on the two sides of the system may be readily understood by reference to the above figure.

Only one coil is shown. It is connected through slip rings to points *C* and *D* of the generator armature. Windings and connections being symmetrical, it is evident that when the terminals of the balance coil *C* and *D* are directly under the brushes, that is, when the point *D* coincides with the point *A* and the point *C* with the point *B*, the balance coil is subjected to the full voltage of the generator and the potential between the middle point *E* and each outside wire is equal to one-half the generator voltage. Also, when the armature has rotated 90° further so that the point *C* and *D* lie directly under the poles, the balance coil is not subjected to a difference of potential and the voltages between the neutral and the outside wires on the two sides of the system are respectively equal to the voltages between *D* and *A*, and *C* and *D*. In any other position of the armature, the voltage between *E* and *A* is the resultant of half the voltage of the balance coil and the voltage of the segment of the armature winding between *D* and *A*. As the voltages generated in equal parts of the armature are equal, the voltage generated in segment *AD* equals that generated in segment *BC*, and, since *E* is the midpoint of the balance coil so that the voltage between *E* and *D* is always equal to that between *E* and *C*, it follows that the voltage between *E* and *A* must always equal that between *E* and *B*, and that *E* is therefore the neutral point at all times.

Armature. The armature winding of the standard Westinghouse 2-wire generator is unchanged except the coils which have the taps brought out and connected to the collector rings.

Fields. The series coils of compound wound 3-wire generators are divided into halves, one of which is connected with the positive and one with the negative side. This is done to obtain compounding on either side of the system when operating on an unbalanced load. To show this more clearly consider the case of a generator with the equalizer in the negative side only and with the majority of the load on the positive side of the system. The current flows from a positive brush through the load and back along the neutral wire without passing through the series field. The generator is then operating as an ordinary shunt machine. If the majority of the load be connected to the negative side, the current flows out the neutral wire and back through the series field, boosting the voltage the same amount as a 250-volt load taking the same amount of current. Such operation is not satisfactory and so the two series fields are provided.

Equalizers. As there are two series fields, two equalizer busses are required.

Terminal boards. Owing to the equalizer connections, two similar terminal boards are supplied, one for each side of the generator.

Ammeters. Two ammeters must be provided for reading the current in the two outside wires. It is important that the current be measured on both sides of the system, for, with ammeter in one side of the system only, it is possible for a large unmeasured current to flow in the other side of the system.

Switchboard connections. One voltmeter is connected across the outside wires. Two ammeters should be used to indicate the unbalanced load. The positive lead and equalizer are controlled by a double pole circuit breaker, the negative lead and equalizer should be likewise protected. Both the positive and negative main leads and equalizers are ordinarily provided with single pole single throw switches.

Unbalanced load. Standard balance coils are supplied of capacity suitable for an unbalanced of 10 per cent of the full load current, that is, a current in the neutral equal to 10 per cent of the full load current of the machine. For example, take 100-kilowatt 250-volt generator. Full load current amounts to 400 amperes, at 250 volts, 10 per cent of this amounts to 40 amperes.

Regulation. The regulation of a 3-wire generator when operating on a balanced load will be the same as any standard 2-wire generator. With 10 per cent unbalance, the variation in voltage between the neutral and outside wires will not exceed 2 per cent below or above normal.

Balance coils. Each of these consists of a laminated core and single winding with a neutral tap brought out from its middle point. Whatever the *A.C.* voltage impressed on the ends of the winding, the voltage between one end of the winding and the neutral is one-half of the total voltage. Winding and core are enclosed in a cast-iron case, which is filled with transformer oil.

In the event it is desired to use a 3-wire generator the foregoing specifications for a 2-wire generator are modified as follows:

Type. The generators are to be direct connected, engine driven, interpole type for 3-wire 125–250 volt direct current, each mounted on a sub-base connected to its engine sub-base. One to have a full load rating of 50 kilowatts at 285 r.p.m. and one to have full load rating of 100 kilowatts at 250 r.p.m.

The armatures and commutators to be built upon ventilated sleeves or spiders, arranged to be pressed on and keyed to shafts.

The field or magnet frames to be provided with screws and liners for adjustment in position.

Frames. The frames of generators to be made of a high grade cast steel or of cast iron of high permeability, sound and free from blowholes. The seats for the pole pieces to be accurately finished, seats for the bolt heads and nuts to be faced.

Pole. The pole to be made of laminated sheet steel, bolted to the frames. The interpole to be steel bolted to the frames.

Field coils. The main field coils to be form wound, provided with ventilating ducts, and be so secured that they may be readily removed without unwinding. The series field will be divided so that one-half will be connected in the positive line, one-half will be connected in the negative line; and so proportioned to automatically give the voltages specified under "Regulation," and be properly insulated in a substantial manner with material of the best quality.

Armatures. The armature to have slotted cores, the windings to be thoroughly insulated, provided with ventilated ducts for cooling the windings and coils to be securely held in place. Preference will be given to 2-phase, 3-wire connections on account of the better balanced voltage. The armature must be balanced both mechanically and electrically.

Commutators. Commutator segments to be of drop forged or hard drawn copper of high conductivity, insulated with mica of even thickness and proper hardness to insure uniform wear; and must run free from sparking, flashing or burning at the brushes at any load or during change of load. They must have ample bearing surface and radial depth for wear.

Brushes. Brushes to be of carbon, and of such size and number as will carry all of the loads covered by this specification without injurious heating.

With a fixed position of the brushes, there is to be practically no sparking, flashing or burning of the brushes, or blackening of the commutator within the limits of the time load specified or to be any injurious sparking at the momentary load specified.

Brush holders. (No change.)

Regulation. The voltage regulation to be 230 volts no-load to 250 volts full load based on a variation of speed in the engine of not more than 2 per cent from no-load to full-load.

With 10 per cent unbalanced load in the neutral wire or 40 amperes for the 100-kilowatt generators and 20 amperes for the 50-kilowatt generator the variation in voltage between the neutral and the outside wires will not exceed 2 per cent above or below normal.

Insulation. (No change.)

Heating effect. (No change.)

Efficiencies. (No change.)

Switchboard. (Must be changed to suit 3-wire system of distribution.)

MOTORS AND CONTROLLING APPARATUS

DIRECT CURRENT

The reasons given for using interpole generators apply more forcibly to direct-current motors. The instantaneous overload is large and more frequent, and the continued overload obtains more often on individual motors than on generators supplying several motors. Also the interpole provides the proper commutating field when motors are run at increased speeds by field control, and consequently with weaker magnetic conditions.

The mechanical construction should be rigid but the weights should be kept down to the safe minimum. Steel frames are therefore desirable from both standpoints.

The bearings should be dust and oil proof.

The efficiency should be high and the overload capacity ample.

The speed should be approximately the same as the full load speeds of induction motors, thus simplifying the application of motors to pumps and fans, as it is desirable in some of the Federal buildings to use alternating-current circuits.

It is desirable to operate motors on 220 (or preferably 230) volts, rather than at 115 volts. Standard commercial speeds and horsepower ratings from 1½ H.P. to 20 H.P. and 230 volts are as follows for interpole motors:

Horsepower	Full load R.P.M.
1½	900
2	850–1200
3	1150–1800
5	850–1100–1800
7½	650–850–975–1150–1700
10	600–730–850–1150–1300–1700
15	600–675–825–1100–1250–1700
20	650–750–900–1100–1700

This table, however, applies to 115 volt interpole motors except 7½ to 20 H.P. motors, inclusive, which are not usually built for 1,700 R.P.M.

The commercial efficiencies of 230-volt interpole motors at full load are as follows:

Horsepower	Rated Speeds				
	600	720	900	1200	1800
1.5			74.5		
2			76.5	77.5	
3			79.0	80.0	79.5
5			83.5	83.5	81.5
7.5	84.5	84.5	84.5	85.5	86.0
10	85.0	85.5	87.0	86.5	86.0
15	86.0	85.5	88.0	88.5	87.5
20	87.5	88.0	88.0	89.0	88.5

The commercial efficiencies of 115-volt interpole motors at full load are as follows:

Horsepower	Rated speeds				
	600	720	900	1200	1800
1.5			72.5		
2			76.5	77.0	
3			79.0	80	78.5
5			82.0	83	80.5
7.5		84.5	84.5	85	
10	81.5	84.5	86.0	86	
15	85.5	85.5	86.0	87	
20	87.0	87.0	87.0	88	

Methods of speed control for direct-current motors. 1. Armature Control, or regulation of the voltage at the brushes by means of an adjustable resistance in series with the armature. Recommended for some service in which speeds lower than normal are desired as in controlling the speed of fans, blowers, centrifugal pumps, etc.

2. Field Control, or regulation of the field strength by means of an adjustable resistance in the shunt field circuit. Recommended for service in which speeds higher than normal are desired, as in operating machine tools.

Armature control. With constant torque, the motor current is constant regardless of the speed. Therefore every change in the controlling resistance in armature control produces a corresponding change in voltage drop in the resistance and a like effect on the motor speed. Moreover, the motor speed remains constant at any adjustment. The motor output is proportional to the product of the torque and speed, and the former remaining constant, the output must vary with the speed. For example: At one-half speed the motor output is one-half that corresponding to the same torque at full speed; and since the voltage at the brushes must be one-half that of the line, the voltage drop in the controlling resistance equals the voltage at the brushes.

That is, one-half the total energy taken from the line is absorbed by the resistance and the efficiency of the motor and controller cannot be over 50 per cent.

Constant reduced speeds with varying torque cannot be obtained by armature control.

Fans, blowers and centrifugal pumps require an unvarying torque at each speed, and with fans and blowers the torque decreases very nearly with the cube of the speed, making this control fairly economical.

For service requiring a continuous operation with full-load torque at reduced speeds, adjustment by armature control is very inefficient, as much energy is lost in the resistance.

Field control. With constant voltage at the brushes, the speed of direct-current motors varies practically in inverse proportion to the change of field magnetism, that is, the weaker the field the higher the speed, and vice versa. The field magnetism changes with the change of shunt field current, though not always in direct proportion thereto. The torque decreases in proportion to the decrease in field magnetism; the horsepower output, being proportional to the product of the speed and torque, remains practically constant throughout the entire range of speed.

With shunt motors, the speed regulation at any given speed is good, in fact, practically constant at all loads within the motor capacity. This is of especial importance to the operation of machine tools and in service of any character where constant speed with varying torque is desired.

Speed control. Starting devices should be provided with automatic control so that a failure of voltage, or excessive overload, will open the circuit and voltage can not again be impressed, on the motor or the starter, without connecting the proper resistance in the circuit. All starters, therefore, should be provided with a no-voltage release so that on resumption of the power full resistance will be inserted between the line and the motor; and either circuit breakers, fuses or magnetically operated switches should be provided so that the excessive overload will not damage the apparatus.

Remote control. Two general principles are employed, the constant time element and limiting starting current on successive steps.

A. The constant time element is desirable where a smooth even acceleration is required as in starting a belt driven load of large inertia.

B. The limiting current method is desirable where starting conditions require acceleration in steps depending on starting current conditions, as with pumps, elevators, and similar service.

Two types of automatic-control auxiliaries are in general use:

A. Float type switch, or a float, in an open tank, which closes the relay circuit, at either the lower or higher predetermined level, and starts or stops respectively the motor, by means of magnetically operated switches.

B. Pressure type, or a pressure gauge, in a closed pressure system, which operates in a similar manner at a predetermined lower or higher pressure.

Armature control. A face plate constant speed-hand operated starter provided with no-voltage release is satisfactory up to 20 H.P. capacity. Drum type controllers should be used from 20 H.P. to 50 H.P. capacities or where frequent starting and stopping duty is required. No-voltage release should be provided in connection with the starters. A fused line switch, circuit breaker or similar device should be provided, with the starter, so that the circuit will be opened on excessive overload, should the operator hold the starting handle on an intermediate resistance point.

All starters should be arranged to automatically cut in the proper resistance, once the circuit is opened, either through voltage failure or excessive overload, so that the motor and controller will be protected on resumption of power. This can be accomplished either mechanically or by means of magnetically operated switches. electrically interlocked, so it is necessary to move the handle to the off position, before again connecting the apparatus in circuit.

Multiple switch starters should be used above 50 H.P. capacities, arranged with interlocks, so the switches can only be closed in proper order, and should be provided with full overload and no-voltage release protection.

The same specifications apply with the addition of proper resistance steps to operate continuously at reduced speeds. A constant speed motor is capable of a small increase in speed, say 15 per cent, by field control, and where necessary, the starters can be arranged with an auxiliary control to increase the speed, by cutting resistance in series with the shunt field.

Remote control. Starters, in addition to the use as indicated by the name, eliminate the personal element, insuring always the same application of the machinery under consideration.

Acceleration is accomplished by means of magnetically operated switches, controlled by relays, and so interlocked that a failure of any of the switches will prevent the motor circuit being closed. Full overload and no-voltage release should be provided. Either face plate or drum type regulators may be used as the master switch only controls the relay circuit.

For remote control speed regulating the master switch should be provided with proper latching mechanism, so continuous operation can be obtained, at reduced speed. Indicating lamps or gauges should be provided to show the operating speed.

Field control. For variable speed the same type of controller should be used as specified under the various sub-divisions under constant speed motors, with the addition of a field regulating rheostat, interlocked with the starter in such a manner that it is impossible to start the motor with weakened field.

ALTERNATING CURRENT MOTORS

Alternating current motors should be of the induction type, with rigid but light construction provided with ample size of bearings to be both dust and oil proof.

Because of the simple mechanical construction, great ruggedness and reliability, squirrel-cage motors should be used for constant speed service, except where a starting torque of more than 1 to 1½ times full-load torque is required, or where it is necessary to keep the starting current below 2½ to 3½ times the normal load current. If more severe conditions must be met, motors having phase-wound rotors should be specified.

The question of starting current on small induction motors is often given undue prominence. In actual practice it is found that even when a large proportion of the total connected load is composed of small squirrel-cage motors, which are frequently started and stopped, that the maximum peak load is but a small percentage increase over the normal load. It is true, that squirrel-cage motors while starting take from 2½ to 3½ times full-load current, but this maximum, as a rule, does not exist more than five seconds, and as the motor speed increases the current falls rapidly. Two or three times full-load current of a motor, which is only 10 per cent of the total capacity of the motors installed, is only about 25 or 30 per cent of the total current taken when all the motors are operated.

The commercial speeds and horsepower of 3-phase, 60-cycle 220-volt, squirrel-cage induction motors are as follows:

Horsepower	Full load R.P.M.
1	1700
2	1135–1710
3	1140–1720
5	560–670–859–1130–1700
7½	560–670–850–1130–1710
10	560–675–850–1125–1710
15	565–680–855–1135–1710
20	565–675–850–1135–1700

The standard gear ratio for back-geared motors is approximately 5 to 1. Motors with a synchronous speed of 1,800 R.P.M. are not usually geared above the 3-horsepower size.

The full-load efficiencies and power factors of the above motors are as follows:

Horsepower	R. P. M.									
	600		720		900		1200		1800	
	PF.	Eff.	PF.	Eff.	PF.	Eff.	PF.	Eff.	PF.	Eff.
1									80	77
2							78	84	80	84
3							81	84	86	85
5	82	81	81	83	83	85	86	84	88	85
7.5	80	84	80	83	83	85	85	84	90	85
10	80	84	84	84	86	85	90	85	90	85
15	84	86	85	86	86	85	89	86	91	86
20	83	87	84	85	85	85	91	87.5	93	87

Auto-starters furnish the most satisfactory means for starting squirrel-cage induction motors. They reduce the voltage initially impressed upon the motor primary, and simultaneously supply the increased current needed for starting, without drawing excess current from the line. For this purpose they are more efficient than any form of rheostatic starter, their internal losses are small, and it is practically impossible to injure the motor or the starter. The essential features are two auto-transformers, by means of which the reduction in voltage in two of the phases is obtained, and a switching mechanism for connecting the motor primary, first across a portion of the auto-transformer taps, and then directly across the line.

The switching mechanism and starter can be enclosed in the same iron casing, or the two can be mounted separately. Contacts of the oil-immersed butt type give the most satisfactory operation.

Motors up to and including 5 H.P. can be thrown directly on the line and should be provided with a fused switch.

Motors over 5 H.P. should have automatic protection.

The starting current being so much larger than full load current fuses or circuit breakers would open at starting, consequently starters should be provided with two sets of line leads, one for starting and one for running. The starting leads may, or may not, be provided with overload protection, according to the starting conditions, but fuses, or a circuit breaker, must always be provided for the running leads.

Auto-transformers should be provided with no-voltage release, and can be provided with overload release when desired.

Remote control starters. Acceleration can be accomplished in two general ways:

A. Magnetic switches operated through relays, by means of a controller.

B. Mechanically operated auto-transformers with bell cranks or rope drive, or where compressed air is available, by means of an air cylinder connected to the starting mechanism of the auto-transformers.

Both devices should be provided with full overload and no-voltage release.

PHASE-WOUND INDUCTION MOTORS

Phase-wound or slip-ring induction motors develop high starting torque without drawing excessive current from the line. They are, therefore, well adapted for driving machinery, requiring a strong starting effort on circuits where close voltage regulation is necessary, as in starting heavy machinery when the motor is operated from a lighting circuit. These motors are especially adapted to constant speed service for operating all classes of constant speed machinery, such as the operation of hoists, pumps, compressors, etc.

With full-load torque these motors will start and accelerate with current not exceeding one and one-fourth times full load.

The secondary electromotive force is that necessary to drive the secondary currents through the windings. It follows that the electromotive force required must depend on the resistance of these windings. A larger resistance means a larger electromotive force for the required current and, therefore, a greater number of secondary alternations or a greater slip, the torque being held constant any variation of the secondary resistance requires a proportionate variation in the slip. If the slip with a torque is 10 per cent, for instance, it will be 20 per cent with double the secondary resistance, or 50 per cent with five times the resistance. The secondary resistance may be in the windings themselves or entirely separate from the machine and connected to the winding through slip rings.

This means that the speed of a phase-wound motor can be varied below synchronous speed by inserting external resistance by means of a proper controller.

The phase-wound induction motor should be used, therefore, when it is necessary to reduce the starting current of the motor on account of resultant effect on the lighting system when the motors are operated from the lighting circuits; when high starting torque is necessary; or when it is desirable to vary the speed of the apparatus which is motor driven.

The commercial speeds and horsepower of 3-phase, 60-cycle 220-volt, phase-wound induction motors are as follows:

Horsepower	Approximately full load speed
5	860-1120-1710
7½	860-1120
10	580-690-860-1140
15	580-690-870-1150
20	580-690-860-1150

The full-load efficiencies and power factors of above motors are as follows:

Horsepower	R. P. M.									
	600		720		900		1200		1800	
	PF.	Eff.	PF.	Eff.	PF.	Eff.	PF.	Eff.	PF.	Eff.
5					80	85	84	83	86	83
7.5					78	85	80	83	87	87
10	77	85	82	86	81	86	85	86		
15	81	86	82	87	83	87	87	88.5		
20	80	87.5	82	87	83	86.5	89	87		

It is preferable in specifications to scale all efficiencies and power factors from ½ to 1 per cent from those given above, and while the best commercial results are desired the specification should not be made too rigid.

CONTROL

Constant speed, hand starting. Drum type controller with auxiliary resistance, should be used up to approximately 100 H.P., the circuit provided with no-voltage and overload release. The starters are only connected with the secondary windings and are used to accelerate the speed by short circuiting successive resistance steps in each phase. All these phases should be interconnected and grounded to prevent shock to operator. The resistance may be integral with or separate from the controller of the motor.

Multiple switch-type starters should be used for larger motors, the switches being interlocked to provide proper sequence of operation. No-voltage and overload release should be provided.

Variable speed, hand operated. Controllers should be in general the same as above except equal resistance steps should be provided so the motor can be run continuously at speeds less than synchronous.

Remote-control starting. Magnetically operated switches should be used to short circuit successive resistances. The switch should be interlocked to insure operation in the proper sequence and be provided with full overload and no-voltage release. Face plate or drum type controller should be used to operate the relay circuit controlling the magnetic switches.

VACUUM CLEANING SYSTEMS

Stationary. The specifications prepared in the office of the Supervising Architect for vacuum cleaning systems of the stationary type with vacuum producers and separators located on permanent foundations, and with a piping system having outlets throughout the building, admit the use of apparatus of both the so-called high-vacuum and low-vacuum types, with certain restrictions. The high-vacuum type is required to use a 1-inch diameter cleaning hose and maintain under test conditions a vacuum equivalent to 12 inches of mercury in a separator that first receives the dust. The low-vacuum systems are required to use a 1½-inch diameter hose and to maintain when operated under test conditions a vacuum equivalent to 6 inches of mercury in the separator that first receives the dust.

For large buildings which do not contain an electric generating plant and in which high-pressure steam is maintained throughout the year, consideration is given to the installation of vacuum producers of the steam jet type. Contrary to the generally accepted opinion, first class devices of this type are, when provided with efficient controlling devices, fully as economical as high-grade steam or electrically driven vacuum pumps. In buildings like hotels, where cleaning must be constantly going on throughout the day, with from one-fourth to one-half the plant capacity in use, the jet producers are far more economical in operation than pumps of any type. In addition to the relative low cost for maintenance and repairs, the steam jet devices have the merit of low first cost, simplicity in construction, and economy of space.

Positive displacement pumps of the piston or double-impeller rotary type are permitted under the specifications.

The reciprocating type of exhauster when fitted with poppet type of valve is limited to a piston speed of 200 feet per minute in order to insure quiet running. When the rotary type of valve is used a piston speed of 300 feet per minute is permissible. Preference is given to machines of the lower speed as making for longer life and fewer repairs.

The specifications for the reciprocating type of vacuum producers require strictly first-class workmanship; no pockets or clearance spaces are allowed in pistons; piston rings are required to fit grooves both in width and depth. Valves are required to be placed in heads and the clearance reduced to a minimum. The cylinders are required to be jacketed; frames must be of ample strength; cross heads and slides are required and all bearings must be lined with anti-friction metal. These specifications are important to prevent the use of vacuum producers of less merit.

Rotary exhausters of the double-impeller type are limited to a peripheral velocity of 1,100 feet per minute to insure quiet running. They are required to be provided with gearing running in oil or grease, and must be fitted with water jet for cooling and sealing the impellers. At all vacua below 12 inches this type of exhauster is more economical than the best reciprocating type; it is practically free from wear, and from damage due to foreign substances entrained in the air entering the exhauster; the first cost is less, and few repairs are required.

Exhausters of the centrifugal type are admitted by the specifications and their speed is limited to a peripheral velocity of 15,000 feet per minute. Exhausters of this type are required to have air-tight casings of aluminum or cast iron, and plain or ball bearings; and preference is given to machines of the type which are provided with vertical shafts so arranged that the weight of moving parts equalizes the end thrust. Machines of the centrifugal type require special high-speed motors, which are subject to extensive repairs. Careful erection is necessary to reduce vibration and noise to a minimum.

This type of exhauster is suitable for low vacuum only.

All positive displacement and all centrifugal types of exhausters installed in Federal buildings are motor-driven.

In all of the cleaning systems installed in Federal buildings a dry separator is required to be placed between the suction lines and the exhauster.

The dry separator must be cylindrical, constructed of sheet steel, and provided with cast iron or steel heads. No bags or screens are permitted to be installed in this separator. The action of separator must be purely centrifugal and the device must intercept not less than 95 per cent of the total dust entering same.

With all positive displacement types of exhauster a second separator is required to be placed between the centrifugal dry separator and the exhauster. The second separator must positively remove all dust from the air before it enters the exhauster. The second separator may be either of the wet or dry type; and if of the latter type may have a bag or core composed of "hush cloth" or other suitable material, which must be properly reinforced to prevent rupture and so arranged that it may be cleaned without dismantling the separator.

If the second separator is a wet separator it may be cylindrical like the dry separators or may be formed in the base of the exhauster.

In either case it must be provided with means for positively mixing the air and water and thoroughly breaking up all bubbles, and must positively separate the water from the air and prevent water and dirt from entering the exhauster.

With the steam jet or centrifugal types of exhausters this second separator may be omitted.

Separators are required to have a cubic contents of 3 cubic feet for each sweeper of plant capacity, for high vacuum and 4.5 cubic feet per sweeper of plant capacity for low-vacuum systems.

The specifications require that all steam jet and positive displacement type of exhausters must be provided with a device for automatically controlling the vacuum. The control must maintain within certain limits a predetermined vacuum in the dry separator. The controlling device may be of the electrical type operated by the vacuum in the dry separator to vary the speeds of the exhauster and maintain a constant vacuum in the dry separator. This type of control when used, requires the motor to have special windings so that its speed may be varied from one-third to full speed by variation of the strength of shunt field only.

The controller may be of the mechanical type which is intermittent in action and which closes the suction of the exhauster when the vacuum reaches a certain point and opens the suction when the vacuum falls 2 to 2½ inches below the determined amount.

The controller may also be of the type that opens the suction of the motor-driven exhauster to atmosphere; or that cuts off the steam to the jet type of exhauster and holds the vacuum in the separator by means of check valves when the vacuum in the dry separator reaches a certain point and closes the air inlet to suction of motor-driven exhauster; or that turns on steam to jet type when vacuum falls 2 to 2½ inches.

All of these control systems are required to effect a saving in power which is determined by operating the exhauster with all hose inlets closed as hereinafter explained under the heading of tests.

Centrifugal type of exhausters do not require any controlling device as features inherent in the design thereof tend to produce and maintain a constant vacuum within the capacity of the machine.

With all positive displacement exhausters a positive acting vacuum-breaker is required to be furnished as a safeguard in the event the control fails to operate.

The power per sweeper required to operate cleaning plants of from four to eight-sweeper capacity when operating the full number of sweepers on stiff-backed carpets has been determined by tests to be as follows:

Type of exhauster	Separators	Power per sweeper	
		High vacuum	Low vacuum
		Kilowatt	*Kilowatt*
Reciprocating	Wet and dry	2.36	2.22
Reciprocating	2 dry	2.15	1.98
Double cam rotary	2 dry	2.06	1.32
Double cam rotary	Wet and dry	2.80	1.80
Centrifugal	1 dry		1.98
	High vacuum		Low vacuum
Steam jet	250 pounds steam per hour		200 pounds steam per hour

The tests were made under the most favorable conditions as regards power consumption, as the air handled is at a minimum, i.e., 43 cubic feet per minute for high vacuum, and 60 cubic feet per minute for low-vacuum. When cleaning bare floors, walls, relief work, or pigeon holes, the amount of air passing through the cleaning tool is practically equal to that passed by an open hose. Capacity tests of sweeping plants are made with hose lines 100 feet long equal in number to the plant capacity, with ends open to atmosphere, under which conditions the high vacuum will handle 55 cubic feet and the low-vacuum 80 cubic feet of free air per sweeper per minute. The power required by the system under test conditions above noted is limited by the specifications as follows:

	Kilowatts per sweeper
6- to 8-sweeper plants	$3\frac{1}{3}$
3- and 4-sweeper plants	$3\frac{1}{2}$
2-sweeper plants	$3\frac{3}{4}$
1-sweeper plants	4

The specifications require each bidder to state the size of motor he proposes to use, which under test conditions must not be overloaded and must not operate under less than three-quarters of its rated power.

The motor must be constructed in accordance with the standard motor specifications prepared by the Supervising Architect; and may have shunt, compound, or interpole windings, as the type of control requires.

In addition to the capacity test hereinbefore described a test is made to determine the tightness of the system. This is done by subjecting the piping to a test under $7\frac{1}{2}$ pounds air pressure, and after all outlet valves, separators, etc., are connected the exhauster is operated at the speed specified, and the power required to operate exhauster under conditions noted must not exceed the following.

	Per cent of power required for capacity test
8-sweeper plants	40
4- and 6-sweeper plants	50
3-sweeper plants	60
2-sweeper plants	65

A test to determine the efficiency of the separators is also made. A number of outlets equal to capacity of system are selected, and on the floor over an area 50 square feet at each outlet, there is spread 6 pounds of dry sharp sand (screened through a 50-mesh screen), 3 pounds of wheat flour and 1 pound of powdered charcoal. Bare-floor cleaning tools are then attached to outlets, using 50 feet of hose, and the material is picked up, recovered from the dry separator, spread out again on the floor and again picked up. This procedure is repeated a third time. At the conclusion of the test the positive displacement exhausters are examined internally, and if a trace of any of the above materials is found it is considered sufficient cause to reject the separators.

If the centrifugal or steam-jet type of exhauster is installed the quantity of material recovered from the separator is weighed and if this be less than 95 per cent of the total material picked up the separator is rejected.

The air piping is standard, black, wrought-iron or mild steel and ends of all pipes are reamed. The fittings on air pipes must have an inside diameter equal to the pipe bore and may be plain or galvanized cast-iron drainage fittings, with a radius of not less than 3 inches at center line when space conditions permit. Fittings with less radius are reinforced at point receiving the impact of the dust. A standard flange union is used at the base of each riser to permit repairs.

Brass screw-jointed clean-out plugs are provided in fittings at turns and at base of each riser, and plugs in 1½-inch line are same size as pipe but are 2 inches in all other lines.

Pipe bends are installed on some lines to reduce the friction.

Wall outlet sweeper cocks are of the flush type and are provided with hinged or screw covers. If latter type of cover is used a safety chain must be provided to secure same to the outlet. The hinged type must close by its own weight and be provided with a rubber disc or ring to make a tight joint.

Floor outlets are located in a brass box set flush with floor, with hinged lid which will not open in a vertical plane and will close by its own weight. Sweeper cocks for high-vacuums are all 1-inch diameter, and for low-vacuums 1½-inch diameter.

A cabinet containing a complete set of tools is required to be provided for each sweeper capacity of the plant, and at least one complete set of tools for each story of the building. The following tools comprise a set:

One 12-inch or 15-inch carpet renovator.
One 12-inch or 15-inch bare-floor brush.
One 12-inch or 15-inch wall brush.
One 4-inch or 6-inch diameter relief clean brush.
One stair-cleaning brush.
One 4-inch or 6-inch upholstery brush.
One corner or crevice cleaner.
One short stem 1 foot 0 inch long.
One long stem 5 feet 0 inch long.
One extension stem 5 feet 0 inch long.
One 45° handle for floor cleaning.
One straight handle for woodwork and wall cleaning; or one straight handle with detachable swivel.

All renovators except the stair cleaners and round brushes have slots within 15 per cent of the following widths: high-vacuum $\frac{1}{4}$ inch; low-vacuum $\frac{1}{2}$ inch.

The lips of carpet and upholstery renovators must be so constructed as to prevent injury to the fabric cleaned and reduce sticking of renovator face to material cleaned.

Handles for tools are either cast metal or tubing, and the bore of same is required to be uniform size throughout and same size as stems.

Stems are either drawn steel No. 21 gauge or brass tubing No. 16 gauge. Stems are 1 inch outside diameter for high-vacuum and $1\frac{1}{4}$-inch outside diameter for low-vacuum. Extension stems for wall cleaning are aluminum.

Carpet renovators are preferred to be cast iron, but either brass or aluminum body with an iron wearing face may be used.

Vacuum breakers are required in the tool handles of high vacuum systems, except when renovators are provided with inrush slots or other vacuum-reducing devices.

For each set of tools provided a hose rack is installed, and for each rack 100 feet of non-collapsible reinforced hose is supplied, which must not weigh over one pound per lineal foot. The hose couplings are either screw, slip, or bayonet-lock type, with smooth bore of practically same diameter as the hose. Screw couplings have ground joints; bayonet-lock joints may have packing washer; and slip joints have permanent steel pieces on end of hose and brass slip coupling.

The size of the plant to be installed is based on the floor area of the building and as to whether said floor area will be carpeted or left bare.

A plant is not installed in a building where the total floor area is less than 50,000 square feet and where the total carpeted area is less than 25,000 square feet.

The following table is used as a guide in determining the size of the plant, and in this connection attention is called to the fact that the tendency of engineers is toward the installation of too large a plant.

Floor area, including basement	Number of sweepers in plant capacity
51,000 square feet to 100,000	2
101,000 square feet to 150,000	3
151,000 square feet to 250,000	4
251,000 square feet to 400,000	6
400,000 and up	8

In preliminary layouts the following space is allowed for the reception of the future plant:

Number of sweepers.	Space for pump and motor	Space for separators
2–3	3 feet by 9 feet 6 inches	2 feet 9 inches by 5 feet
4	3 feet by 10 feet	3 feet by 5 feet
6	4 feet by 11 feet 6 inches	3 feet by 5 feet
8	5 feet by 14 feet	4 feet by 7 feet 6 inches

The minimum height allowed for the small plants is 6 feet 6 inches and for the large plants 8 feet 6 inches.

A space of 2 feet 6 inches square is allowed for the control board and a space of 1 foot 6 inches square for the muffler which is required with reciprocating exhausters. The muffler discharge is taken into the smoke breeching on stack side of damper; or if conditions demand a separate exhaust pipe is run above the roof.

If possible, the risers are located so that all parts of building to be cleaned may be served with not over 50 feet of hose on any outlet.

The sweeper cock outlets are located in basement, in the post-office workroom, and in the lobbies and corridors; occasionally in court room, but never in an office room.

If conditions require, risers may be so located that 75 feet of hose will be required to clean all parts of the building.

Most of the standard makes of vacuum producers are tapped as follows:

Capacity	High vacuum		Low vacuum	
	Inlet	Exhaust	Inlet	Exhaust
	Inches	*Inches*	*Inches*	*Inches*
1 sweeper	2	2½	2½	3
2 sweeper	2½	3	3	4
3 sweeper	3	4	4	5
4 sweeper	4	5	4	5
6 sweeper	5	6	5	6
8 sweeper	5	6	6	8

The pipe sizes for the systems to be installed in Federal buildings are indicated on drawings. They are given for both the high and low-vacuum systems, and are determined by the following method:

A table of equalization of pipes, in which each size is given an arbitrary value, is used. To find the size of pipe equivalent of any number of pipes of given size, add the values assigned each size of pipe, and select the pipe size which is the sum of their arbitrary values:

Pipe size	1″	1½″	2″	2½″	3″	4″	5″	6″
Constant	10	30	60	110	175	380	650	1050

To determine the size of the risers, assume that only 50 per cent of the total number of sweeper outlets on a riser will be in use at any one time and allow the equivalent of one 1-inch pipe for each outlet in use for high-vacuum and the equivalent of one 1½-inch pipe for each outlet in use on low-vacuum systems. No riser to be less than 2-inch diameter and no branch to a single outlet from riser to be made less than 1½-inch diameter.

Example: Assume an 8-story building with eight sweeper outlets on each riser and with four outlets in use on each riser, under which conditions for high-vacuum $4 \times 10 = 40$ which under the rule requires a 2-inch riser. For low-vacuum $4 \times 30 = 120$, which under the rule requires a 2½-inch riser. To ascertain the size of mains required, start at the last riser on any line and make the main line the same size as riser until the next riser is connected to main; then make size of the main equivalent to the risers connected thereto until the pipe size is the same as the tapping of the machine used.

Example: Assume a 6-sweeper plant in an 8-story building, using a high-vacuum system. The main will start 2 inches and when the second riser is connected $60 + 60 = 120$, which under the rule will make the main 2½ inches. When the third riser is connected $120 + 60 = 180$, and the main will be 3 inches. When the fourth, fifth, and sixth risers are added the main will be 4 inches, and when the seventh riser is added the main will be 5 inches in diameter, which is the size of machine tapping.

For a low-vacuum system the main will start at $2\frac{1}{2}$ inches and when the second riser is connected $110 + 110 = 220$, which under the rule makes the main 4 inches; the 4-inch size is maintained until the fourth riser is connected, $110 \times 4 = 440$, and the main is made 5 inches, which is the size the machine is tapped for. If additional risers are added the main would not be increased. Whenever possible the machine is located near the center of the building and two or more branch mains are used and connected together as one main near the separator. Each of the branches may be made equal to the machine tapping if the number of risers connected to such branch main requires such size under the rules stated. The connection from the point of junction of the mains to the separator may be same size as the largest branch main, or may be increased if desired.

No account is taken of basement sweeper outlets when calculating the size of air mains. The basement branches, and any other branches in which material picked up must be *lifted,* are always made $1\frac{1}{2}$ inches for high-vacuum and 2 inches for low-vacuum. Lifts are to be avoided unless absolutely necessary.

The above method of calculating the mains is used for all high-vacuum systems, and also for all low-vacuum systems when the distance from the machine to the end of furthest riser does not exceed 400 feet.

When the distance is greater than 400 feet the size of mains is calculated from tables of friction loss, etc., and all pipe sizes are checked so that the velocity of the air in the main will not be less than 2,000 feet per minute when the plant is operating at full capacity.

SPECIFICATION

A specification such as is used by the office of the Supervising Architect is as follows for a four-sweeper plant:

VACUUM CLEANING SYSTEM

General description. The work included in this contract shall be the installation of a complete vacuum cleaning system for the removal of dust and dirt from rugs, carpets, floors, stairs, furniture, shelves, walls, and other fixtures and furnishings throughout the building, and for conveying said dust and dirt to suitable receptacles located where shown, together with all of the necessary cleaning tools, hose, piping, separators, exhauster, motor, etc., as hereafter more fully specified.

Exhauster. Furnish and erect where shown on drawings Nos. V. C. 488 and V. C. 489 an approved air exhauster having a nominal capacity for four sweepers at either high-vacuum, 12 inches, or low-vacuum, 6 inches of mercury, and that shall operate without overload under the test conditions hereafter specified.

The exhauster in all of its details shall be made of the best materials suitable for the purpose, and shall be of approved design and construction, and may be either of the positive displacement (piston or rotary) or of the multistage fan type.

The piston type of exhauster shall be double acting and so designed that the cylinder clearance shall be reduced to a minimum, or suitable devices shall be employed to minimize the effect of large clearance.

The induction and eduction valves may be either poppet, rotary, or semirotary, and shall operate smoothly and noiselessly.

The piston packing shall be of such character as to be practically air tight under working conditions and constructed so that it will be set out with its own elasticity without the use of springs of any sort. If metallic rings are used, they must fill the grooves in which they are fitted, both in width and depth, and must be concentric—that is of the same thickness throughout. The joint in the ring or rings to be lapped in width but not in thickness and if more than one ring is used they are to be placed and doweled in such position in their respective grooves so that the joints will be at least one-quarter of the circumference apart.

The piston shall have no chamber or space into which air may leak from either side of the piston. All openings into the body of the piston must be tightly plugged with cast-iron plugs.

The piston-rod stuffing box to be of such size and depth that if soft packing is used it can be kept tight without undue pressure from the gland. If metallic packing is used, it must be vacuum tight without undue pressure on the rod. Proper means shall be provided for the continuous lubrication of the piston rod.

The exhauster of the piston type shall be fitted with an approved crosshead, suitably attached to the piston rod; machines having an extended piston rod for guide purposes will not be acceptable.

The rotary displacement exhauster shall be of the two-impeller type.

Exhausters fitted with sliding blade or blades will not be acceptable.

All parts of the exhauster shall be rigid enough to retain their shape when the machine is working under maximum load conditions.

The impellers must be machined all over and must be of such shape and size that they will revolve freely and not touch each other or the casing (cylinder) in which they are placed, but the clearance must be of the least possible amount consistent with successful operation.

The shafts must be of steel with the journals ground to size.

The journal boxes must be long and rigidly supported by the headplates and placed far enough from the headplates to allow the placing of proper stuffing boxes on the shafts.

The shafts must be connected by two pairs of wide-faced steel gears, cut from the solid and securely fastened to the shafts. The gears shall run in suitable oil-tight gear boxes that shall be fitted with adequate and suitable means for lubrication.

The displacement type of exhaustion may be used for either high or low-vacuum system.

Centrifugal fan type. The centrifugal fan exhauster to be so proportioned and constructed as to handle the volume of air required at the specified vacuum with the least possible loss. The housing shall be of aluminum or cast iron, made in sections. The housing must be air tight.

The fan wheels to be constructed of aluminum or steel or other metal, properly reinforced, and, if cast, must include hub and arms complete in one piece. If the fan wheels are built up, they must be strongly riveted to cast-iron, steel, or brass hubs or spiders.

The fan wheels are to be secured to shaft with a feather and set screws.

The shaft of fan exhauster shall be vertical and the wheels so mounted that their weight will equalize or partly equalize the end thrust, or may be horizontal and end thrust taken care of with ball-bearing thrust rings.

The journal boxes for all of the above-named types of exhausters shall be of the design best adapted for the purpose and must be fitted with first-class approved continuous lubricating devices, either sight feed, ring oiler, or any other kind best suited for the work or design of apparatus used.

Reciprocating piston exhauster shall be provided with the necessary devices for the removal of the heat generated by friction and compression, that shall prevent the temperature of cylinders or eduction chambers rising more than 100° F. above the surrounding atmosphere after two hours' continuous operation under full-load conditions.

The rotary type of exhaust must be provided with the necessary water connections to properly seal and cool the pump.

Speed. Reciprocating exhauster with poppet valves shall operate at an average piston speed not exceeding 200 feet per minute, with rotary valves not exceeding 300 feet per minute.

Rotary exhausters shall not exceed a peripheral speed of 1,100 feet per minute at tips of impeller.

Centrifugal fans shall not exceed peripheral velocity of 15,000 feet per minute when running under specified full-load conditions.

Base plate, foundation, etc. Provide suitable base plate to rigidly support the exhauster and its motor as a unit, which shall be large enough to catch all drip of water or oil. Provide a raised margin and pads for feet of exhauster frame, motor and anchor bolts, high enough to prevent any drip from getting into the foundation or on the floor.

Provide suitable foundation of brick or concrete, to which the base plate shall be firmly anchored. The foundation shall be built on top of the cement floor of the basement, which is not to be cut, but shall be picked to afford proper bond for the foundation.

Construct the foundation of such a height as to bring the working parts of the machine at the most convenient level for operating purposes. Exposed parts of the foundation to be faced with best grade white enameled brick. If the base plate does not cover the foundation the exposed top surface is to be finished with enameled brick, using bull-nose brick on all edges and corners.

Drive. The exhauster shall be driven by an electric motor, which may be direct connected to the exhauster shaft or be operated with a metal-link belt of the noiseless type, or by cut gearing. Chain and gearing is to be of ample size and strength for their work and must run without undue noise or wear. Means shall be provided to take up the slack of the chain belt. Furnish and place a suitable metal guard over belt and sprocket wheels that shall prevent oil being splashed outside of the base plate and prevent clothing being caught.

If the exhauster is operated through cut gearing the gears must be inclosed in an oil and dust-proof case, which shall be fitted with means for copious and continuous lubrication of same.

Finish. The air exhauster and motor and the base plate shall be finished in a first-class manner, filled, rubbed down, and painted at least one coat at the shop, and after installation shall receive two more coats, finishing tint to be as directed.

Electric motor. Motor to be of such size that when operating under test conditions same will not be under less than three-fourths nor more than full-load condition.

Motor to be of standard make, approved by the Supervising Architect.

Motor to be wound for 220 volts direct current.

Motor armature to be of tooth-core construction, with windings thoroughly insulated and securely fastened in place, and must be balanced both mechanically and electrically.

Commutator segments to be of drop-forged copper of high conductivity, well insulated with mica of even thickness and of such texture as will give uniform wear of copper and mica, and shall run free from sparking or flashing at the brushes.

Commutator to be free from all defects and have ample bearing surfaces and radial depth as provision for wear.

Brushes to be of carbon mounted on common rocker arm and to have cross-sectional area of not less than 1 square inch for each 40 amperes of current at full load. Rocker may be omitted in event interpolar motor is used.

Brush holders to be of a design to prevent chattering, with individual adjustment in tension for each brush by means of a spring.

Bearings to be of approved self-oiling type.

Bidders are required to state in their proposal the rated horsepower and speed of motor.

Insulation resistance. There shall be an insulation resistance between the motor frame and the field coils, armature windings, and brush holders, and between shunt and series field coils of not less than 1 megohm.

Motor must be capable of standing a break-down test of 1,500 volts alternating current for one minute.

Efficiency. The efficiencies of motor furnished must not be less than—

One-half load, 83 per cent.
Full load, 88 per cent.

Heating. The maximum rise in temperature of any part of the motor after a continuous run at full-rated load for a period of three hours shall not exceed 90° F. above the surrounding atmosphere.

Shop tests and inspection. The insulation, heating, and efficiencies of the motor shall be determined by actual tests at the shops where the motor is constructed under conditions specified.

The contractor shall give 10 days' notice direct to the Supervising Architect of his readiness for the shop tests of the motor.

The department reserves the right to waive shop tests or inspections or such portions as may in the opinion of the Supervising Architect be expedient, it being understood that such portions not fully waived shall be exacted after the installation of the apparatus.

The Supervising Architect reserves the right to waive the shop test in the presence of a representative of this office and in lieu thereof to require the contractor to submit certified test sheets of motor in duplicate.

Tablet. Furnish and place where indicated a marble tablet not less than $1\frac{1}{4}$ inches thick, supported by a substantial angle-bar frame so placed that there will be a space of not less than 1 foot 4 inches behind the tablet.

Mount on this tablet one 75-ampere, double-pole, single-break knife switch; one double-pole circuit breaker, with auxiliary carbon break and overload release, with range from 25 to 60 amperes; and one starting rheostat, with no-voltage release, of proper capacity to control the motor. The rheostat and all of the connections shall be on the back of the tablet.

The space between the tablet and wall shall be inclosed with a removable diamond-mesh grille of No. 10 iron wire in channel frame.

All connections between the tablet and motor are to be made by this contractor.

Two No. 3 feeders are now in place and terminate near the new switch tablet which is to be furnished by this contractor. If these feeders are not of sufficient length to reach the new tablet, they must be spliced to new feeders, the splice being made in a junction box.

All wires are to be run in standard steel conduit, except those that are so short as to be self-supporting, and these are to be cord wrapped or otherwise protected. No wire smaller than No. 12 to be used.

All material and workmanship to be strictly first class. Electrical work must show an insulation resistance of at least 1 megohm, and to be in strict accordance with the latest edition of the "National Electrical Code."

Automatic control. Suitable means shall be provided in connection with the motor of reciprocating or rotary exhausters that will maintain the vacuum in the separators within the limit of the machine at point found to be most desirable, irrespective of the number of sweepers in operation.

This controller may consist of an automatic device, mounted on the tablet hereinbefore specified, to change speed of motor controlled by the variations of the vacuum in the system. If this method of regulation is used, the motor shall be provided with special windings that will permit a speed variation of from one-third full speed to full speed by variation of shunt field only, without undue sparking at the brushes.

In lieu of above method of control suitable means may be provided in the exhauster, or as an attachment thereto, which will automatically throw the exhauster out of action by admitting atmospheric pressure to the exhauster only, but not to the system; or that shall cause suction from the system to cease whenever the vacuum in the separators rises above the point considered desirable, and throw the exhauster into action when the vacuum falls below the established lower limit.

Drawings. Contractor will be required to submit for approval, after award of contract, drawings in triplicate showing exhauster, motor, separators, connections, and type of control, in detail.

Said drawings must be approved by the Supervising Architect before any of the work is installed.

Vacuum breaker. In addition to the controlling devices above specified, if reciprocating or rotary exhauster is used, there shall be placed in the suction pipe to the exhauster an approved positive-acting vacuum breaker having opening equivalent to the area of 1-inch diameter pipe and set to open at 12 inches for the high vacuum system.

If centrifugal fan-type exhauster is used, it must be designed so that the maximum vacuum shall not exceed 6 inches of mercury and no vacuum control or vacuum breaker will be required.

Dust separators. Furnish and place at some convenient point between the vacuum mains and the exhauster one dry separator having a volume of not less than 12 cubic feet for a high or 18 cubic feet for a low-vacuum system.

If a displacement type of exhauster is installed, there shall be furnished an additional separator to be placed between the first separator and the exhauster cylinder, which may be either wet or dry, as desired, and may be contained in the base of the machine or consist of a separate tank.

If centrifugal type of exhauster is installed, but one separator, and that a dry separator, will be required.

Separator tanks shall be constructed with steel shells, with either cast-iron or steel heads, and be fitted with suitable bases or floor stands for support.

The interior arrangements of the dry separator first receiving the dust shall be such that no part of same will receive the direct impact of the dust. No cloth bags nor metal screens will be permitted in this separator. It must be so constructed that it shall intercept not less than 95 per cent of the dust entering same.

If two dry separators are used, the second separator must be arranged so that none of its appliances are liable to be ruptured by air currents or of being drawn into the piping or exhauster, and the arrangement of same must be such that the separator can be easily cleaned without dismantling same.

Wet separators, whether separate from or integral with the base of the machine, must be provided with an attachment which will positively mix the air and water, thoroughly break up all bubbles, separate the water from the air, and prevent any water entering the exhauster cylinder.

If wet and dry separators are used in combination, suitable means must be provided to automatically equalize the vacuum between them upon the shutting down of the exhauster.

The separators must be provided with suitable openings for access to the interior for inspection and cleaning, and the interior arrangement of the separators must be such that they may be readily cleaned without dismantling.

All parts of the wet separator tank not constructed of non-corrosive-metal must be thoroughly tinned or galvanized both inside and outside. The interior of the wet separator formed in base of exhauster shall be painted with at least two coats of asphalt varnish or other paint suitable to prevent the corrosion of the same.

Separators must be provided with all necessary valves or other attachments for successful operation, including a sight glass for the wet separator, through which the interior of same may be observed, and a 30-inch iron case mercury column attached to the dry separator first receiving the dust.

Wet separator shall be connected to the water-supply main and to sewer, which pipes are in place in the machine room, as directed. A running trap with clean out shall be installed in the waste line between separator and sewer.

Piping. The vacuum mains shall be installed as indicated and noted on drawings.

The pipe size indicated on the drawings, inclosed in circles, are to be followed for a high-vacuum system and the pipe sizes inclosed in squares are to be followed for a low-vacuum system. No increase or decrease in these pipe sizes will be allowed.

Pipes. All pipe conveying air is to be standard, black, wrought iron, or mild steel, screw-jointed pipe, and is to be smooth inside, free from dents, kinks, fins, or burrs. Ends of pipe to be reamed to the full inside diameter and beveled. Bent pipe to be used in mains where necessary.

Care must be taken in erecting pipe to maintain as nearly as possible a smooth, uniform bore through all pipe and fittings.

Waste and water pipe, in connection with wet separator and jacket (if used), except waste pipe below basement floor to be standard galvanized wrought iron or steel, screw-jointed pipe, free from burrs. Waste pipe below the basement floor is to be best grade, "extra heavy" cast-iron pipe, with lead-calked joints.

Fittings. All fittings to be tough, gray cast iron, free from blow holes or other defects; smooth castings in all cases.

All fittings on vacuum lines must have inside diameter through body of same size as pipe bore, and all fins, burrs, or rough places must be removed.

Fittings on vacuum lines are to be black or may be galvanized.

Where space permits, all tees and elbows, must have a radius at center line of not less than 3 inches.

All fittings having less than 3-inch radius must have the thickness of metal on sides receiving the impact of the dust increased 50 per cent above standard thickness.

A standard cast-iron flange union is to be provided on the connection to each riser near the base.

Fittings on water lines to be standard galvanized beaded fittings.

Fittings on waste line above basement floor to be galvanized, recessed, screw-jointed drainage fittings, and those below basement floor to be "extra heavy" cast iron with hub joints.

Horizontal overhead pipes to be supported with substantial pipe hangers spaced not more than 10 feet apart.

Where exposed pipes pass through walls or floors of finished rooms, they must be fitted with cast-iron, nickel-plated plates.

Clean-out plugs. Brass screw-jointed clean-out plugs are to be provided in lines at all turns where indicated on the drawing. The clean-out plugs to be 2-inch diameter, except in the 1½-inch lines, where clean outs are to be same diameter as the line.

Exhaust connection. Exhaust pipe from the exhauster is to be run up to the basement ceiling and along same into the vent shaft and up same to attic and through the roof, as indicated. The opening in roof is to be flashed with 6-pound sheet lead and provided with counterflashing.

The exhaust pipe is to be fitted with an approved first-class exhaust muffler not less than 12 inches in diameter and 60 inches high, closely riveted and constructed of galvanized iron not less than ⅛ inch thick, and in event an exhauster requiring lubrication is furnished this muffler is also to be arranged so that it will also be an efficient oil separator. Drip connection to be arranged at bottom of muffler.

Sweeper outlets. The following number of outlets are to be provided: Basement, three; first story, six; second story, three; third story, three; fourth story, three; fifth story, three, sixth story, three; attic, three.

The sweeper outlets may be fitted with hinged screw covers or caps with rubber gaskets. If screw cover is used, same is to be provided with a safety link, brass, nickel-plated chain. If hinged type of outlet is used, same is to be arranged to be self-closing when hose is removed.

Outlets coming through finished walls or partitions are to be flush pattern.

Outlets on risers run exposed against walls are to be set close up against bead of fittings.

If contractor desires to use other form of connection than above described, which is equally satisfactory, same must be submitted to the Supervising Architect for approval after award of the contract.

Tool cases. Furnish eight approved hardwood cabinet-finished cases for cleaning tools. Each case to be made as light as possible and of convenient form for carrying by hand and provided with a complete set of cleaning tools, each securely held in its proper place and fitted with lock and key, clamps, and conveniently arranged handles.

In this specification the word "renovator" is used to mean that portion of the tool which is in contact with the surfaces cleaned; the word "stem," that portion connecting the renovator and handle, and the word "handle," that portion held in the hand and to which the hose is attached; the word "cleaner" is used to mean a complete cleaning tool.

Cleaning tools, etc. The following cleaning tools are to be furnished for each case:

One renovator not less than 12 inches nor more than 15 inches wide, for cleaning carpets.

One renovator not less than 12 inches nor more than 15 inches wide, for cleaning bare floors.

One brush renovator not less than 12 inches nor more than 15 inches wide, for cleaning walls.

One dusting brush renovator not less than 4 inches nor more than 6 inches in diameter, for cleaning relief work.

One brush renovator suitable for stair cleaning.

One upholstery cleaner not less than 4 inches nor more than 6 inches wide for cleaning upholstery furniture.

One corner and crevice cleaner.

One short stem about 1 foot long.

One long stem about 5 feet long.

One extension tube about 5 feet long.

One 45° handle for floor cleaning.

One straight handle for woodwork and wall cleaning.

Both kinds of handles to be provided with couplings for hose and stems to be provided with hand-operated full-area roundway valves. The cut-off valve must be easily operated and be indicating and when closed be practically air tight. All movable parts that are in contact must be arranged so as to be protected from dust and from wear from this cause.

The renovators for carpets, bare floors, walls, and relief work to be arranged with adjustable swivel joint, so that same can be set at an angle with stem from 45° for regular use to an angle of about 80° for use under or back of furniture and other similar places. This movable joint to be made so that it can be easily adjusted and firmly set and held in place, or so arranged that lips of cleaning tool will always remain in contact with surface cleaned, and constructed so that fitted surfaces are not exposed to dust, and the air currents when deflected to impinge only upon surfaces which are of heavy metal and where such wear as occurs will not affect the operation and handling of the tool.

In lieu of the above adjustable joint in the renovators themselves special couplings, one for each stem, may be furnished in addition to the straight couplings, which can be used in connection with the renovator mentioned so as to bring the latter to the 80° angle required.

All renovators, stems, and handles are to be as light as is consistent with strength and ability to withstand cutting action of dust.

All renovators, except round and stair brushes, are to have slots of the following widths:

For high-vacuum system, $\frac{1}{4}$ inch wide.

For low-vacuum system, $\frac{1}{2}$ inch wide.

A variation not exceeding 15 per cent in width of slots as given above will be allowed on carpet renovator.

A variation of 25 per cent increase will be allowed on brush renovators.

If renovators, with air-intake slots, or other form of vacuum reducer, or short-circuiting opening, are used, the area of the main slot may be increased 20 per cent. The area of intake opening or slot is not to exceed 10 per cent of the net area of main slot.

The lips of carpet renovators and upholstery cleaner to be of such proportions and form as will prevent injury to the fabric, and such width as will reduce to a minimum the sticking of renovator face to the material being cleaned.

An approved $\frac{1}{2}$-inch diameter finished-brass, nickel-plated, positive-acting vacuum breaker, with an adjustable brass spring, inclosed within a removable cap, is to be provided in the handles of a high-vacuum system, and must be connected to handle by $\frac{1}{2}$-inch diameter standard screw-pipe connection so as to be removable for cleaning, etc. In event air-intakes slots or other vacuum-reducing devices are used in the high-vacuum system, the vacuum breakers in the tool handles may be omitted. In event centrifugal exhauster which will not produce more than 6 inches of vacuum is used, the vacuum breakers in tool handles may be omitted.

Handles to be cast metal or combination of cast metal and tubing.

Stems to be not less than 1 inch outside diameter for high-vacuum system and $1\frac{1}{4}$-inch outside diameter for low-vacuum system. Air passages in handles and swivels to be same diameter as inside of stem.

The handles are to have long-radius curves, and connections are to be made without shoulders or projections in the bore against which dust can strike. Parts of handles receiving dust at change of direction are to have ample metal to allow for cutting effect of dust.

Stems to be drawn-steel or brass tubing, not less than No. 21 United States standard gauge thick if steel and not less than No. 16 Brown and Sharpe gauge thick if brass.

Carpet renovators to be made preferably of cast iron, as light as possible, or may be made of cast brass with iron wearing face.

All brushes to be of substantial construction, with best quality bristles set in close rows and as thick as possible, skirted with rubber, leather, or chamois skin so that all air entering renovator will pass over surface being cleaned.

All renovators and brushes must be provided with proper rubber or other approved buffers to prevent marring the woodwork.

Upholstery cleaners are to have inlet slots or openings of such size and form as to absolutely prevent drawing in loose covering of furniture.

Upholstery and corner cleaners are not to be arranged for use with stems and handles, but are to have their own handles permanently attached, and be provided with hose couplings, and without valves and vacuum breakers.

All metal parts of renovators, stems, and handles are to be finished, and all except aluminum parts nickel plated.

Hose racks. Furnish and properly secure in place, where directed, one hose rack in basement, first, second, third, fourth, fifth, sixth, and attic stories (eight racks in all).

The racks to be constructed of cast iron, galvanized or enamel finish, and each rack to be suitable for holding 75 feet of hose of required size.

Hose. There must be furnished with each hose rack 75 feet of non-collapsible hose in three 25-foot lengths.

Hose to be not less than 1 inch inside diameter for high-vacuum system and not less than $1\frac{1}{2}$-inch inside diameter for low-vacuum system, and must be smooth inside and outside.

The hose to be best quality rubber hose, reinforced in best manner to absolutely prevent collapse at highest vacuum obtainable with the exhauster furnished and to prevent collapse if stepped on. Weight of hose to be not over 16 ounces per linear foot.

Couplings for hose to be either screw, slip, or bayonet-lock type, with smooth bore of practically same diameter as inside of hose. The couplings to have least possible projection outside of hose dimensions and be well rounded, so as not to injure floors, doors, furniture, etc.

Screw couplings to have ground joint; bayonet joints may have packing washer, and slip joints to have permanent steel T pieces on ends of hose and brass slip coupler. All ends of hose couplings to have outside ferrules securely fastened in place. Simple conical slip joints slipped into ends of hose without ferrules will not be acceptable.

Samples. The successful bidder, after award of contract, if required by the Supervising Architect, must submit to the Supervising Architect for approval one cleaning-tool case supplied with full set of cleaning tools, one of each kind of outlet, and one piece of vacuum hose, 12 inches long, supplied with coupling at one end.

Tests. The contractor is to make tests hereinafter described in the presence of the Department's representative and must furnish all the labor necessary to make said tests.

Operation test. After the complete installation of the apparatus, a capacity test of the exhauster shall be made. Four outlets shall be selected by the Department's representative, but not more than two on any one riser, and to each shall be attached 100 feet of hose, of size required by the system, with end open. To be acceptable, this test must show that the exhauster shall maintain the specified vacuum when running at or under the specified speed, and the power consumed shall not exceed 14 kilowatts.

To test the tightness of the system and the effectiveness of the vacuum control, the exhauster shall be run with all outlets closed, and the power consumed shall not exceed 50 per cent of that at full load.

Test of cleaning tools. The plant shall be operated by the contractor in presence of the Department's representative, and a test made of each kind of cleaning tool furnished. The tool shall be attached to a 50-foot length of hose attached to an outlet selected by Department's representative, and under normal working conditions each tool must satisfactorily perform the work for which it was designed. Dust and surfaces to be cleaned shall be furnished by the contractor.

Test of separators. At each of four points, near four outlets selected by the Department's representative (not more than two outlets on any one riser), the contractor shall furnish and spread on the floor, evenly covering an area of approximately 200 square feet for the four outlets, or 50 square feet for each outlet, a mixture of 24 pounds of dry, sharp sand that will pass a 50-mesh screen, 12 pounds of fine wheat flour, and 4 pounds of finely pulverized charcoal.

Fifty feet of hose of size required by the system used shall be attached to each of the four outlets, and the surface or surfaces prepared for cleaning shall be cleaned simultaneously by operators provided by the contractor, until all of the sand, flour, and charcoal has been taken up, when the exhauster shall be stopped and the dirt removed from the dry separator and spread on the floor again, and the operation of cleaning repeated until the mixture has been handled by the apparatus four times. If, after thoroughly flushing the system, at completion of the above run, any dust or mud is found in the cylinder, ports, or valves chambers of the displacement exhauster, or if less than 95 per cent of the dirt removed is found in the dry separator of the centrifugal exhauster, it shall be deemed sufficient ground for the rejection of the separators.

Painting. After the completion of the specified tests, all exposed galvanized-iron or tinned work in connection with this apparatus, not specified to be otherwise finished, shall be primed with paint suitable for galvanized or tinned surfaces, and then given two additional coats. Machinery shall be painted as already specified, and all other work shall be given finishing tints as selected or approved by the custodian. Black iron shall be primed with a coat of red lead and linseed oil.

Portable apparatus. For Federal buildings containing less than 50,000 square feet of floor area, a portable vacuum cleaner complying with the following specifications is supplied at a cost of about $125.00.

Vacuum producer shall be of rugged construction with well-proportioned parts. It must be capable of displacing not less than 50 cubic feet of free air per minute at the end of not less than 15 feet 0 inch of cleaning hose, and must produce a vacuum when outlet is closed of not less than 22 inches of water.

Motor shall be of standard make, of ample power to drive vacuum producer.

The maximum power consumption when operating either with open hose or with renovator on carpet shall not exceed 360 watts.

The motor must be fitted with a suitable device to permit same to be started with a 10-ampere fuse in the circuit.

Dust separator shall be constructed of metal and be so arranged that it can be easily cleaned. The capacity and arrangement of dust separator shall be such that at least one peck of dust may be picked up and the machine still do effective work and the separator intercept all dust and dirt without cleaning the dust separator.

The vacuum producer, motor, and dust separator shall be mounted as a unit. No wood shall be used in any part of this unit. The combined unit shall be mounted on wheels or casters and fitted with suitable handles, and shall not weigh more than 80 pounds.

The following equipment to be furnished with the cleaner:

25 feet flexible reinforced new code No. 14 double conductor with Edison screw attachment plug.

Not less than 15 feet of reinforced rubber-lined cleaning hose not less than 1¼-inch inside diameter.

One brass or aluminum tubular handle not less than 4 feet long.

One extension tube 5 feet long.

One carpet renovator with cleaning slot not less than 8 inches long by ⅜ inch wide, with cast-iron wearing face.

One hard-wood floor tool.

One floor brush.

These may be arranged to be attached to carpet renovator if desired, and shall have cleaning slots with areas equal to or greater than that of carpet renovator.

One wall brush not less than 5-inch diameter.

One upholstery tool with not less than 3-inch cleaning slot.

One corner cleaner.

One blowing nozzle.

All renovators to be made of aluminum or of brass, the former being preferred, and all parts except aluminum to be nickel-plated.

The foregoing specification for portable cleaning apparatus was used by the Department until October, 1911, at which time the Bureau of Standards undertook the testing of these devices for the Treasury Department with a view to selecting the best apparatus. When the tests are completed a new specification will be issued.

OPERATING DATA

About a year ago the Chief Mechanical and Electrical Engineer was made directly responsible to the Supervising Architect for the satisfactory and economical operation of the mechanical equipment of the six hundred and fifty-two completed and occupied buildings under the control of the Treasury Department.

The majority of the buildings are very small, and the mechanical equipment consists of a direct steam or hot-water heating apparatus, and a gas and electric direct lighting system supplied with either gas or electricity from local companies. In these small buildings the matter of engineering personnel, purchase of supplies and fuel, etc., is merely routine.

It has been for years the practice of the Department to purchase coal on the B.t.u. basis for all buildings where the cost exceeded $1,500.00 per annum, but this method of purchase is about to be discontinued except for the large buildings.

When coal is purchased under the B.t.u. system the specifications state what kind of coal is desired and limit the amount of volatile matter and ash, which will be permitted.

Each bidder offers such coal as he thinks will meet the specification, and gives in his proposal the following information relative to the coal he proposes to supply:

Number of B.t.u. per pound of dry coal as received.
Percentage of ash per pound of dry coal.
Cost per ton of coal.

As there is always a variation in the ash content of coal offered by the various bidders, it is necessary, in order to reduce all to the same basis, to fix a standard ash content and make an allowance for variation from same.

The lowest ash content stated by any bidder is made the standard, and all other coal offered is brought to this basis by adding 2 cents per ton from the price quoted for each 1 per cent or fraction thereof the ash content exceeds the arbitrary standard.

When all proposals have been brought to the same basis in regard to ash content, the lowest price quoted per 1,000,000 B.t.u. is readily ascertained by the following formula:

$$\text{Cost per million B.t.u.} = \frac{1{,}000{,}000 \times \text{price per ton of coal}}{2{,}240 \times \text{B.t.u. per pound of coal}}$$

When the coal purchased under the B.t.u. system is delivered at the building, samples are taken and sent to the Bureau of Mines for analysis, the result of which determines the payment to be made for the coal delivered. If the analysis shows that the contractor has fulfilled his agreement, no more and no less, the contract price is paid; otherwise, corrections above or below the contract price are made for variation in B.t.u. and ash.

The correction for B.t.u. is made by the following formula:

$$\frac{\text{Delivered B t.u.} \times \text{contract price per ton}}{\text{Contract number of B.t.u. per pound}} = \text{price paid per ton}$$

For example: If the contractor stated that his coal contained 14,000 B.t.u. per pound and the price per ton was \$3.00, and the coal delivered contained 14,300 B.t.u. per pound, he would be paid per ton

$$\frac{14{,}300 \times 3}{14{,}000} = \$3.0643.$$

The price to be paid must be further corrected for any variation in ash content. For all coal, which by analysis contains less ash than that established in the proposal, a premium of 2 cents per ton for each whole per cent less ash is paid. An increase of 2 per cent in ash over the contract amount is tolerated without deduction, but for any excess a penalty is exacted in accordance with the following table:

Ash as established in proposal	No deduction for limits below	Cents per ton to be deducted							Maximum limits for ash
		2	4	7	12	18	25	35	
		Percentages of ash in dry coal							
Per cent									
5	7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	12
6	8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	13
7	9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	14
8	10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	14
9	11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	15
10	12	12–13	13–14	14–15	15–16	16–17	17–18		16
11	13	13–14	14–15	15–16	16–17	17–18	18–19		16
12	14	14–15	15–16	16–17	17–18	18–19	19–20		17
13	15	15–16	16–17	17–18	18–19	19–20	20–21		18
14	16	16–17	17–18	18–19	19–20	20–21	21–22		19
15	17	17–18	18–19	19–20	20–21	21–22			19
16	18	18–19	19–20	20–21	21–22	22–23			20
17	19	19–20	20–21	21–22	22–23				21
18	20	20–21	21–22	22–23					22

When local conditions permit the choice of either gas or electricity as the illuminating medium, preference is given to electricity on account of the vitiating effect of gas on the air in a building, and also on account of the great amount of heat generated by the gas, which is a decidedly objectionable feature during the summer months.

With lighting fixtures designed to give equal illumination using either tungsten lamps or Welsbach inverted or Junior lamps, the cost of illuminating a building will be about the same for gas and electricity if gas is selling at $1.00 per 1,000 cubic feet and electricity at 5 cents per kilowatt-hour.

Where conditions permit the use of either gas or electricity their relative costs are carefully analyzed in each case, on the assumption that the full connected lighting load of a building will be in service four hours per day. The following data are used in connection with the gas lighting:

Pilot uses $\frac{1}{15}$ foot of gas per hour and burns continuously.

Welsbach inverted gas lamp equipped with Holophane reflector uses 3.5 feet of gas per hour and gives 350 effective lumens.

Welsbach "Junior" uses 2 feet of gas per hour and gives with average reflector used 150 effective lumens.

Welsbach upright lamp uses 5 feet of gas per hour and gives about 300 effective lumens.

The prices quoted for electricity occasionally contain as an inducement the free renewal of carbon or Gem lamps. The use of carbon lamps is not economical under any conditions, and the free renewal of Gem lamps is figured as being worth about $\frac{1}{4}$ cent per kilowatt-hour or less, depending on the number of said lamps it is desirable to use in a given building. They are confined mostly to cord drops and to fixtures subjected to excessive vibration, tungsten lamps being used elsewhere almost exclusively.

A large number of the old buildings have fixtures designed to give proper illumination with carbon lamps, and for such buildings 40-watt tungsten lamps on low efficiency rating are ordered. These lamps on the low efficiency rating use 37 watts, give 28 candlepower, and last 2,000 to 3,000 hours. In buildings having fixtures designed for 40-watt tungsten lamps the lamps are ordered on the high-efficiency rating.

Under certain favorable conditions 25-watt and 40-watt tantalum lamps are used, and are ordered for high or medium efficiency as the conditions demand.

APPENDIX

COMMERCIAL PRACTICE

IN REGARD TO FACTORY HEATING AND FORCED HOT-WATER CIRCULATION SYSTEMS

While the following two chapters are not strictly applicable to Federal buildings, they are incorporated herein as containing much valuable information of general interest.

The papers were written by heating and ventilating engineers in the office of the Supervising Architect, the first by Mr. H. C. Russell and the second by Mr. Leon A. Warren, who are specially qualified to treat of their respective subjects, the former by reason of several years' employment with one of the leading fan manufacturers, and the latter through his connection with a firm specializing on the forced hot-water system of heating.

FACTORY HEATING

[NOTE: Most of the calculations in this paper were made on a slide rule, which accounts for insignificant arithmetical errors. References will frequently be made to the section of this book which treats of the heating and ventilation of Federal buildings, and to curves and tables which will be found in the back of the book.]

Systems in use. Practically there are only two systems for heating factory buildings, i.e., the fan system, and direct steam or hot water, each having its various modifications.

The fan system as a general rule has the following advantages: Great flexibility, in that air can be cut off from unexposed portions of a building and a large part of it forced to the more exposed portions: absence of leaky pipes overhead; less liability of freezing; affords positive ventilation; the humidity of the air inside the building can be controlled; and lower steam pressure is required to maintain circulation, which is an important consideration if exhaust steam is used for heating without a vacuum system.

Direct radiation has certain advantages in places where a fan might stir up dust to settle upon freshly painted or varnished surfaces.

FAN SYSTEM

Apparatus. The apparatus usually consists of a fan to circulate the air, a prime mover to drive the fan, a heater to heat the air, and a set of distributing ducts to carry the hot air to the desired points. Air washers are seldom used except where food products are handled, or where there are special considerations, such as humidity control, etc.

Fans. Centrifugal fans are usually employed, although the disc fan is used in small buildings where the ducts are very short.

The ordinary type of centrifugal fan is known as the "steel plate" fan. It usually has 8 blades. The capacity of a fan is expressed in cubic feet of air per minute handled by the fan. The conditions under which a fan works must be known, because they have a preponderating influence upon its performance. Tests by the writer, coupled with data from various sources indicate the formula given below when proportions of fans are as hereinbefore stated for 8-blade fans.

Capacity.

$C.F.M.$ = cubic feet air handled per minute by the fan.
D = diameter of wheel in feet.
N = revolutions of wheel per minute.

$C.F.M. = 0.44D^3N$, as a formula for ordinary factory heating.

Power required.

$$B.H.P. = \frac{D^5N^3S}{12,500,000}, \text{ for average factory heating.}$$

Symbols same as before, except S, which equals 1.00 for air handled at 0°, and for any other temperature as t—

$$S = \sqrt{\frac{460}{460+t}}.$$

If T should be below 0° it would of course be considered negative.

The B.H.P. is the power actually applied to the fan shaft.

The above formula for power is for a wheel about 6-foot diameter. For smaller wheels add 5 per cent for each one foot difference in diameter.

Sirocco fans. The proportions of these fans have been previously stated. The capacity and power for ordinary factory heating are as follows, the symbols being the same as used heretofore:

$$C.F.M. = 1.10D^3N.$$

$$B.H.P. = \frac{D^5N^3S}{2,250,000}.$$

A test of an 8-foot multiblade fan showed that the fan delivered 75,600 C.F.M. at 149 R.P.M. against a static pressure on the outlet of 1.11 inches of water (inlet free), with a B.H.P. equal to 33.9, at 74° temperature and barometer at 29.76. In this case the outlet was 64 inches x 64 inches instead of the standard size used by the manufacturer.

The above formulae for capacity and power given for heating work are based on having a set of discharge ducts which shall equalize to the standard fan outlet (not *blast areas*, which is usually about 40 per cent of the area of fan outlet), as explained hereafter. Or, to put it in another form, the formulae are correct when the pressure due to the velocity of air at the fan outlet is about 40 per cent of the total friction losses in the heater and ducts.

Double-inlet fans. Double-inlet fans are not often used in factory work, as single-inlet fans usually make a more compact outfit.

Cone fans. These fans have a large field of usefulness in heating and ventilating work where the power must be reduced to a minimum. They require large ducts and much floor space and are seldom used in factories.

The reason for the low power consumption is that in the case of a steel plate fan the air is taken from the periphery of the wheel by means of a scroll, the outlet of which must be relatively small to prevent a so-called "back-lash" of air, resulting in a high velocity of air through this outlet. If large ducts are used this velocity will be reduced and a great part of the pressure in the fan, required to produce this high velocity in the beginning, will be lost. In the case of the cone fan this high velocity is never produced, as the inlet, which represents the highest velocity, is usually about 50 per cent greater in area than the inlet or outlet of a steel plate fan which would be selected to do the same work.

However, a steel plate fan of which the standard outlet equals the area of the discharge ducts will handle the air with less power than a cone fan, because its true mechanical efficiency is higher than that of a cone fan.

The following formulae apply to cone fans:

$$C.F.M. = 48\,D^3N.$$

$$B.H.P. = \frac{D^5N^3S}{14{,}000{,}000}.$$

Care should be exercised in every detail of cone fan installations. The combined area of the air ducts should not be less than the discharge area of the wheel, i.e., the circumference times width of periphery, and the free area of the heater should be about the same as the area of air ducts.

The following facts have been determined both theoretically and practically for all kinds of centrifugal fans:

The C.F.M. varies directly as the speed; the pressure varies directly as the square of the speed; and the brake horse-power varies directly as the cube of the speed.

The above are true, of course, only so long as conditions of the inlet and outlet resistance are maintained the same.

The indicated horse-power of the prime mover may vary about as the square of the speed, depending upon the kind of prime mover used; but this discrepancy is due to a change in the efficiency of the prime mover at different loads. The power actually applied at the fan shaft will vary exactly as the cube of the speed.

At the same speed as the resistance is inserted in the inlet or outlet, as by the closing of a damper, the capacity and power will decrease and the pressure will increase.

The "blast area" of a fan is the area of discharge opening over which the fan will maintain a dynamic pressure equal to the pressure corresponding to the peripheral velocity of the fan tips. When this area is increased the pressure will decrease, and vice versa. Many authorities state that the pressure does not increase on reduction of the area of discharge below blast area, but the writer has always found that it does with 8-blade fans.

The blast area need not be considered in ordinary heating or ventilating work, as the restriction should never be great enough to cut the effective area of discharge down to blast area, which is about 40 per cent of the area of fan outlet, as previously stated.

Disc fans

In this type of fan much depends upon the number of blades, their angle, whether straight or curved, etc. Disc fan outfits are uniformly constructed as "blow through" type. In small buildings these fans will give satisfaction for heating, but a large margin of safety must be allowed, as their operation is materially affected by many apparently trifling things. For fans with about twelve blades the following formulae may be used:

$$C.F.M. = AD^3N.$$

$$B.H.P. = \frac{D^5N^3S}{C}.$$

All symbols are the same as previously given except A and C, which are as follows:

Case I. Free inlet and delivery, as a fan set in a window to supply air or to exhaust from a large room.

Case II. Delivering or exhausting air through not more than the equivalent of 100 feet of straight pipe the diameter of the fan.

Case III. Delivering air through same amount of piping and a heater not more than 20 pipes deep, and with velocity through heater not over 1,000 feet per minute.

Straight-blade Disc Fan

	"A"	"C"
Case I	0.70	42,500,000,000
Case II	0.60	33,000,000,000
Case III	0.50	27,000,000,000

Propeller type

	"A"	"C"
Case I	0.85	46,000,000,000
Case II	0.65	40,000,000,000

In Case II the peripheral velocity of wheel should be not less than 5,000 feet per minute, and in Case III not less than 7,500 feet.

The free area of the heater should not be less than the area of the fan, and the main air duct about equal to free area of the heater.

With the same fan and the same conditions as to inlet and outlet, the capacity, pressure, and power vary in the same manner as given for steel plate fans of the centrifugal type; but when a disc fan is running at a set speed and the inlet or outlet is restricted (as by the closing of a damper) the power will increase, which is just the reverse of what happened with a steel plate fan. The increase is so rapid that it is perfectly possible for the fan to take three times as much power with the damper fully closed as it would with the damper fully open. An engine on this increased load would slow down without damage, but a motor not protected by some kind of overload-release would be burned up in short order. This feature therefore requires care, especially in connection with motor-driven fans. In the case of some of the curved-blade disc or propeller fans the increase of power with the insertion of resistance would not be so noticeable, as such fans have to some extent the properties of centrifugal fans.

HEATING COILS

Heaters used for steam are usually the cast-iron sectional-base type, with heating surface composed of 1″ wrought-iron pipe, or the all cast-iron heaters such as the "Vento" made by the American Radiator Company.

In some makes of the sectional-base type the base is divided into two compartments by a horizontal partition, one compartment being for steam and the other for condensation. This partition may be solid, or water seal inside the base may connect the two chambers. In the former case, which is the preferable arrangement, a third connection called the bleeder is necessary to take care of the water of condensation which drains back into the steam compartment.

In some cases a plain box base is used which has no interior partitions of any kind.

The curve sheets, etc., in the back of this book, and the formulae given in a preceding chapter on heating and ventilation, give all data required as to temperature rise, condensation, friction, etc.

For factory work the velocity through the heater is usually about 1,200 feet per minute, and the heater 20 to 24 pipes deep.

Tappings. For exhaust or low-pressure steam with gravity returns the tapping of the base should be as follows:

Pounds steam per hour per section	Steam tap	Drip tap	Bleeder tap
	Inches	*Inches*	*Inches*
80	2	1¼	¾
160	2½	1½	¾
320	3	2	1¼
480	3½	2½	1¼
950	4	2½	1½

The standard "Vento" tapping is 2½ inches for steam and return, but 3 inches or 3½ inches tappings for the feed sections may be obtained on special order.

The "Vento" has, of course, no bleeder connection. The drip connection should be one-half the diameter of steam connection plus 1-pipe size.

The writer has seen successful installations in which the quantities of steam supplied by tappings were almost double those given above. If the mains are short and the water line is 3 feet or more below the coils the quantities may be increased 25 per cent; and another 25 per cent may be added if the coils are "Vento" or "top feed."

Steam and return piping. The steam pipe is usually carried overhead from a convenient point on the exhaust line or from the boiler. The return is usually carried in a pipe trench discharging into a pot trap, a hot well, a feed pump and receiver, or a return trap. Sometimes it is wastefully trapped into the sewer.

For gravity work the writer uses D'Arcys formula, which when simplified for steam entering at 5 pounds pressure is—

$$D = \sqrt[5]{\frac{LW^2}{KP}} \text{ when}$$

D = diameter of pipe in inches.
L = length of pipe in feet.
W = pounds steam per minute.
P = loss of pressure allowed, usually taken as 1 pound per 300 feet of steam travel.
K = a constant varying with the size of pipe as follows:

Diameter (inches).....	1	2	3	4	5	6	7	8
K equals..............	104	140	160	169	173	180	183	187

For steam above 30 pounds pressure, make steam main one-half of the diameter given above; between 15 pounds and 30 pounds make diameter two-thirds that given by the formula; below 15 pounds same as given by formula.

Return main one-half diameter of steam main plus 1 pipe size and make it "wet." As a rough rule the bottom of the coil should never be less than 2 feet above the water line in receiver, pump governor, trap, or whatever is used.

High and low pressure steam. Most authorities agree that pressure on coils should not be over 5 pounds for best circulation. Arrangements should always be made to use live steam through a pressure-reducing valve to supply the heaters when the main engines which normally supply the exhaust steam are not running.

PRIME MOVERS

Engines are quite generally used in factory work. They are usually direct-connected to the fan without fly wheel or governor, as the fan wheel is a good fly wheel and prevents the engine from speeding because the power required increases so rapidly as the speed increases.

Vertical engines are generally used except the very largest fans. On the direct-connected or fixed-eccentric engines, most makers set the cut-off at 50 per cent, but in figuring for sizes the cut-off should be taken as about 5-16.

If exhaust or low-pressure steam is used in the coils the fan engine exhaust should be connected through an oil separator into the low-pressure main. If steam at high pressure is used in the coils the fan-engine exhaust is usually connected through an oil separator into a separate section of the heater-coil, usually the outside section. This section would of course have to have separate return trap, etc. from the sections on high pressure.

No engine exhaust should be connected to a heating system without a back pressure valve at a convenient point on the exhaust line to regulate the back pressure carried on the engine.

If motors are used they should be direct-connected to the fan when the speed is high enough to warrant it.

Flange couplings are quite generally used for both engines and motors, although some form of flexible coupling is often used, and sometimes where heavy loads are to be carried the fan and prime mover shaft is in one piece.

Belts. Belts should have the "pulling" side on the bottom if possible. The horse-power transmitted per inch of width by a leather belt $\frac{1}{4}$ inch thick at various speeds is as follows:

Velocity in feet per second	Horse-power
10	0.84
20	1.75
30	2.58
40	3.32
50	3.98
60	4.51
70	4.91
80	5.15
90	5.20

For other commercial thicknesses of belt the horse-power transmitted varies directly as the thickness, but the maximum velocity for any belt for good operation may be considered as 90 feet per second.

Pulley centers should be preferably 10 or 20 feet apart, depending upon relative sizes of pulleys. Long slow-moving belts give best service. Centers less than 8 feet apart will seldom be satisfactory.

Chain-drives. For short centers and considerable reductions in speed some of the patented chain-drives give good results, although they are not always entirely noiseless.

Sprockets should generally not be more than 4 feet apart, and the "pulling" side of the chain should run on the top; because if the "loose" side ran on the top (as in the case of belts) the links would be liable to bind on the sprockets.

Gears, etc. Occasionally back-geared motors are resorted to, but gears should be avoided where possible.

Humidifiers. In textile mills and certain other kinds of factories the humidity of the air must be under absolute control. This can best be accomplished by an air washer and humidifier.

In one well-known system the air is first drawn through a spray-type air washer and eliminator. The water supplied to the washer is heated, the temperature of this heated water being controlled automatically by a special controlling apparatus.

In very cold climates it is advisable to put in a tempering coil to avoid the possibility of the washer freezing.

The conditioning of air for textile mills as regards its relative humidity has been reduced to a science. When such problems are encountered it is best to obtain the advice of some of the reliable firms which manufacture such apparatus and guarantee results.

Spinners have found that the cost of installation and operation of the best humidifying apparatus is small compared with the consequent profits in better yarns and the reduced loss in manufacture.

In factories where the humidity control need not be so exact, some of the simpler and cheaper devices may answer the purpose. One of the simplest is to place a large pan of water in the air duct, install a steam coil to heat the water, and have the supply of water regulated by a float valve to maintain a constant level. Sometimes a jet of steam blown into the air, the supply to which is controlled by a humidostat, will be satisfactory, but it is liable to produce bad odors.

When designing fans, etc., for this kind of work it is important to remember that the weight of air per cubic foot decreases very markedly as the point of saturation is approached. Any engineer's handbook will give the necessary information.

Ducts and flues. Ducts and flues are usually made of galvanized iron of the following gages:

Round ducts

To 15 inches dia.	No. 26 U.S.S. gauge
16 inches to 30 inches dia.	No. 24 U.S.S. gauge
31 inches to 42 inches dia.	No. 22 U.S.S. gauge
43 inches to 54 inches dia.	No. 20 U.S.S. gauge
55 inches to 72 inches dia.	No. 18 U.S.S. gauge
73 inches and up	No. 16 U.S.S. gauge

Rectangular ducts

Up to 18 inches wide	No. 26 U.S.S. gauge
19 inches to 26 inches wide	No. 24 U.S.S. gauge
27 inches to 40 inches wide	No. 22 U.S.S. gauge
41 inches to 72 inches wide	No. 20 U.S.S. gauge
73 inches to 84 inches wide	No. 18 U.S.S. gauge
85 inches and up	No. 16 U.S.S. gauge

By "wide" is meant the longest dimension.

No. 26 U.S.S. gauge weighs 0.91 pounds per square foot
No. 24 U.S.S. gauge weighs 1.16 pounds per square foot
No. 22 U.S.S. gauge weighs 1.41 pounds per square foot
No. 20 U.S.S. gauge weighs 1.66 pounds per square foot
No. 18 U.S.S. gauge weighs 2.16 pounds per square foot
No. 16 U.S.S. gauge weighs 2.66 pounds per square foot

In estimating weight allow from 15 per cent to 25 per cent for allowable overweight, laps, and waste in the making, according to the simplicity of the work.

Underground ducts when used are usually made of brick, built rectangular in shape, with arched top, and plastered smooth on the inside. Terra cotta sewer pipe is sometimes used.

Vertical flues are usually made of galvanized iron, but in textile mills and the like they are usually built in the walls and plastered inside. Flues when built in outside walls should be, if possible, lined with fire-clay flue lining, which has some insulating qualities.

Air outlets. When overhead ducts of galvanized iron are used an outlet is usually a branch taken from the main pipe and turned at such an angle as to discharge toward the wall at a point about 8 feet above the floor. Each outlet should be equipped with an adjustable spring damper controlled by a pair of jack-chains reaching to about 7 feet above the floor.

When brick or tile vertical flues are used and so spaced (as is usually the case) as to require no branch piping, a screen or mill damper is used.

Systems of distribution. This is the most difficult part of the work, where experience is at a premium and a knowledge of what has failed is worth even more than a knowledge of what has been successful. It is specially important to refrain from trying to make the air perform any unusual "stunts," and no pipe should be turned on a radius of throat less than the diameter or width of the pipe.

Make it a general rule not to get over 30 feet from an exposed wall and not over 20 feet above the floor. This would apply to a one-story factory building with no ceiling, and, say, a saw-tooth roof construction. Such a building up to 60 or 70 feet wide could be heated with one line of piping in the center. From this up to about 150 feet wide the heating could probably be done with two lines.

Under a smooth ceiling air blown from an outlet toward an exposed wall, even with a low velocity, will heat evenly from 50 to 150 feet away, depending on conditions, chief among which is the location of the foul-air outlet, which should be at the floor line on the same side of the room as the hot-air inlet.

Usually the foul-air or vent ducts are omitted in factories, but many such buildings are tightly constructed and the heating will be more uniform if foul-air ducts are used. When air is to be recirculated a system of openings for the return of air to the fan should be provided if necessary. Such openings should be arranged to give a circulation of air in the rooms.

Care should be taken in regard to allowing for stair wells, elevators, etc., that might short circuit the air back to the fan.

It often happens that apparatus must be on a platform some distance above the floor. In such cases when the air is to be recirculated the discharge branches must be led down columns, etc., to about three feet above the floor, or a return circulating duct must be dropped from the inlet of the heater to about three or four feet above the floor; this duct to equal in area the free air space in the heater. One or the other of these things must be done, otherwise the air will circulate around the top of the building and never reach the breathing line. If both are done it may be possible to keep the breathing line warmer than the roof trusses.

Cone connections. The fan inlet is usually connected to the heater casing by a "cone;" a "collar" should never be used. Plenty of room must be allowed between the fan inlet and the heater, and as a rule no part of the connection must be allowed to form an angle of less than 60 degrees with the side of the fan. If this is not observed a considerable portion of the heater may be "dead."

Heat losses. The following heat losses have been extensively used with good results. They will be found somewhat higher than those applicable to Federal buildings on account of the uniformly inferior construction of factory buildings.

The losses given are B. t.u. per square foot per hour per degree of difference in temperature inside and outside.

Various wall surfaces.

4-inch brick	0 68
8-inch brick	0 46
12-inch brick	0 33

16-inch brick	0.27
20-inch brick	0.23
24-inch brick	0.20
28-inch brick	0.18
32-inch brick	0.16
36-inch brick	0.15
40-inch brick	0.13

Above is for brick walls not plastered.

Heat loss through concrete walls, as given by Mr. W. W. Macon in Metal Worker, March 11, 1911, is as follows:

2-inch concrete	0.69*
4-inch concrete	0.55*
6-inch concrete	0.47*
8-inch concrete	0.49
10-inch concrete	0.35*
12-inch concrete	0.43*
16-inch concrete	0.37
20-inch concrete	0.33
24-inch concrete	0.30
28-inch concrete	0.27
32-inch concrete	0.25
36-inch concrete	0.23

Those marked * are ascribed by Mr. W. W. Macon to Prof. Rietschel, and for ordinary construction should be increased 25 per cent at least.

Unlined corrugated iron or metal	0.84
Corrugated iron or metal over t. and g. boards	0.17

For roof surfaces:

Unlined slate	0.82
Slate over t. and g. boards	0.30
Unlined metal	1.30
Iron over t. and g. boards	0.17
Patent roof (tar, gravel, etc.) over t. and g. boards	0.30

For floors:

Concrete on ground	0.30
Wood close to ground	0.10
Dirt	0.23

For glass:

Single window	1.20
Single skylight	1.50
Single monitor	1.40
Double window	0.56
Double skylight	0.62

All the above are for south exposure. Add as follows: 10 per cent to the north, east, and west exposure; 10 per cent to the total exposure in addition to this if heated in daytime only; 30 per cent to the total exposure in addition to the first if heated in daytime only and unusually exposed; 50 per cent to the total exposure in addition to the first named if heated only at long intervals.

The loss of heat from galvanized ducts carrying hot air can be determined by the formula:

$$t_1 - t_2 = \frac{50\,S(t_1 - t_0)}{C + 25S}, \text{ when}$$

t_1 = temperature of air entering duct.
t_2 = temperature of air leaving duct.
t_0 = temperature of air outside of duct.
S = square feet of surface of duct exposed.
C = cubic feet of air per hour passing through duct.

The B.t.u. lost per hour $= \dfrac{C(t_1 - t_2)}{55}$.

MECHANICAL VACUUM SYSTEMS

These systems are often used on the larger heating installations in factories. They are able to reduce the back-pressure on the engine to little above atmospheric pressure by removing air and condensation by means of a vacuum pump attached to the return lines.

MECHANICAL AIR-REMOVAL SYSTEMS

These systems are often used in factory work. They are able to carry the back pressure on the engines slightly above atmospheric pressure in that they keep the air removed from the system.

It may be well to call attention to the fact that with any of the vacuum or air removal systems there will always be a back-pressure on the engines equal to the friction head of the steam in the mains; but when the air is quickly and effectively disposed of this friction head is comparatively small.

Example. Let us assume the data for an imaginary building and go through the various steps in the design of a factory heating system.

Assumed data:

32,100 square feet concrete floor.
12,250 square feet wall glass.
6,200 square feet 12 inch brick wall.
5,400 square feet single skylight.
31,500 square feet tar and gravel roof.
710,000 cubic feet contents.
Steam main 200 feet long.
Return main 200 feet long.
Recirculated air.
Heat to 55° in 0° weather outside.
Dimensions of building 321 feet x 100 feet x 22 feet.

Calculations for exposure:

Floor,	32,100 × 0.30 × 25	=	214,000 B.t.u. per hour.
Glass.	12,500 × 1.2 × 55	=	805,000 B.t.u. per hour.
Wall,	6,200 × 0.33 × 55	=	112,000 B.t.u. per hour.
Skylight,	5,400 × 1.0 × 55	=	302,000 B.t.u. per hour.
Roof,	31,500 × 0.30 × 55	=	520,000 B.t.u. per hour.
Contents,	710,000 × 55 ÷ 55	=	710,000 B.t.u. per hour.
Total		=	2,689,000 B.t.u. per hour.
Add 7.5 per cent for total exposures		=	202,000 B.t.u. per hour.
Add 10 per cent factor safety		=	268.900 B.t.u. pre hour.
Total exposure		=	3,159,000 B.t.u. per hour.

Assumed temperature of air at outlets, 120°. 120° − 55° = 65° which is the drop in temperature of the air called "diffusion." 65° × .2375 (the specific heat of air at constant pressure) = 15.4 B.t.u. given off from each pound of air circulated, to heat the building.

3,159,900 ÷ 15.4 = 205,000 pounds air per hour to be circulated by the fan.

Allow about 10° drop of temperature in the ducts and if a "draw through" apparatus is used, as is always preferable, our fan will be handling air at 120° + 10° = 130°.

205,000 pounds per hour × 14.8 ÷ 60 = 49,400 *C.F.M.* handled by the fan at 130°.

Fan required.

Our formula for 8-blades fans is $C.F.M. = .44\ D^3 N$. The peripheral velocity in factory work with 8-blade fans is usually about 5,600 feet per minute.

$$
\begin{aligned}
\text{Therefore } N &= 5{,}600 \div \pi D = 1{,}785 \div D \text{ and} \\
C.F.M. &= 0.44 \times 1{,}785\, D^2 = 786\, D^2 \text{ from which} \\
D^2 &= C.F.M. \div 786 \text{ substituting, we get} \\
D^2 &= 49{,}400 \div 786 = 63 \text{ therefore} \\
D &= \sqrt{63} = \text{(say) } 8 \text{ feet.} \\
N &= 5{,}600 \div \pi D = 223 \quad \text{Revolution per minute.}
\end{aligned}
$$

$$B.H.P. = \frac{D^5 N^3 S}{12{,}500{,}000} = \frac{(8)^5 \times (223)^3 \times 0.89}{12{,}500{,}000} = 25$$

Engine required.

Assumed pressure at the throttle 80 pounds. A 10 x 12 engine at this pressure and at 223 R.P.M. will indicate about 32 H.P.

Sirrocco fan required. About 3,500 feet per minute is the usual peripheral velocity with this style of fan in factory work.

$$C.F.M. = 1.1\ D^3\ N$$

But $N = \dfrac{3500}{\pi D} = \dfrac{1110}{D}$ from which is obtained $C.F.M. = 1.10 D^3 N$

$$= \frac{1.1 D^3 \times 1110}{D} = 1220 D^2.$$

$$D^2 = \frac{C.F.M.}{1220} = \frac{49400}{1220} = 41.6.$$

$$D = \sqrt{41.6} = 6\tfrac{1}{2} \text{ feet} = 78 \text{ inches.}$$

$$\text{Now} \quad N = \frac{C.F.M.}{1.1 D^3} = \frac{49400}{1.1 \times 6.5^3} = 164 \text{ R.P.M.; and}$$

$$B.H.P. = \frac{D^5 N^3 S}{2{,}250{,}000} = \frac{(6\frac{1}{2})^5 \times (164)^3 \times 0.89}{2{,}250{,}000} = 20.$$

Heater. As 205,000 pounds of air per hour are handled by the fan and raised from 55°, the temperature of the room, to 130°, the temperature at the outlet of the heater, this will require $205{,}000 \times 75° \times 0.2375 = 3{,}650{,}000$ B.t.u. per hour.

Wrought-iron pipe heater. If it is decided to use a heater 24 rows deep the formula is:

$$V = \left[\frac{A(T - t_0)\ (Bt_0 + t - t_0)}{C(t - t_0)}\right]^2$$

Substituting,

$$V=\left[\frac{1.80\,(687-515)\,(1.00\times 515+590-515)}{535\,(590-515)}\right]^2 = 20.6 \text{ feet per}$$

second × 60 = 1235 feet per minute.

$$\frac{49400}{1235} = 40 \text{ square feet free area.}$$

A section 36 pipes wide and pipes 9 feet 0 inches and 9 feet 3 inches would have 36 × $9\frac{1}{8}$ × 24 = 7,900 linear feet = 2,630 square feet heating surface, and since the free area is practically one-half the gross area for 1 inch pipes on $2\frac{3}{4}$ inch centers, the free area is: Width of heater = 36 × $2\frac{3}{4}$ = 99 inches = $8\frac{1}{4}$ feet × $9\frac{1}{2}$ feet (height) = $78\frac{1}{2}$ square feet. (gross) ÷ 2 = $39\frac{1}{4}$ square feet free area. Velocity therefore = 49,400 ÷ $39\frac{1}{4}$ = 1,260 feet per minute = 21 feet per second.

Checked by formula hereinbefore given:

$$\text{B.t.u.} = A\sqrt{V}\ (T - t_0).$$

Substituting

B.tu. = $1.8\sqrt{21}\ (687 - 515)$ = 1,420 per square feet per hour.

The total B.t.u. is 3,650,000 per hour ÷ 1,420 = 2,570 square feet. So use 36 pipes wide, 24 deep, and 9 feet 0 inches and 9 feet 3 inches high.

To use a Vento heater. Reference to the curve sheet in the back of this book will show that for 5 inch centers standard-depth section with air entering at 50° a 5-section depth heater would raise the air from 50° to 125° at a velocity of about 1,400 feet per minute. This is practically equivalent to raising air from 55° to 130°, which was the required rise of temperature in the case cited. The air quantity, 205,000 pounds per hour, equals $\frac{205{,}000}{60\times 0.075}$ = 45,600 *C.F.M.* at 70°.

(The Vento curves are based on air volumes, measured at 70°).

Now 45,600 ÷ 1,400 = 32.6 square feet free area in the heater.

See table of free areas of Vento heaters in back of this book, and note that a heater 21 sections front, 50 inches high sections and two tiers high would have 16.13 × 2 = 32.25 square feet free area and $283\frac{1}{2}$ × 10 = 2,830 square feet surface.

Steam and return piping. 3,650,000 ÷ 965 (the latent heat of steam at low pressure) = 3,800 pounds of steam per hour. The formula for steam mains was:—

$$D=\sqrt[5]{\frac{LW^2}{Kp}}.$$

Substituting $L = 200$ feet, $W = 63$ pounds (steam per minute), and $p = .67$ pounds, and trying first $K = 180$, which is assuming for trial that D will come 6 inches:

$$D = \sqrt[5]{\frac{200 \times 63 \times 63}{180 \times 0.67}} = 6650 = 6 \text{ inch diameter.}$$

For a vacuum system a main 200 feet long to carry 3,800 pounds of steam per hour should be 7 inches diameter.

38,000 pounds steam per hour ÷ 5 sections = 760 pounds per hour with pipe coil for each section and 3800 ÷ 10 = 380 pounds steam per hour with the "Vento" coil, for each group. Refer to gravity work the steam connection to each section of 4-row pipe coil should be 4 inches and the connection to each group of "Vento" coil should be $3\frac{1}{2}$ inches diameter. If in the pipe coil the style of section having a "bleeder" connection to the base is used use a $2\frac{1}{2}$ inch diameter drip and $1\frac{1}{4}$ inch diameter bleeder for gravity:

Webster pump. 3,650,000 ÷ 250 = 14,600 square feet equivalent direct radiating surface.

3,800 pounds ÷ 360 = 11 – 1 inch water-seal motor valves,

The Webster "pump factor" $(11 \times 100) + 14{,}600 = 15{,}700$. Refer to table for pump factors and note that a $4\frac{1}{2}$ inch x 6 inch x 8 inch pump will be the size to use.

Proportioning air pipes. Air pipes are usually proportioned by the formula:

$$N = \sqrt{\left(\frac{A}{B}\right)^5} \text{ in which}$$

A = Diameter of larger pipe.
B = Diameter of smaller pipe.
N = The number of pipes of the smaller size to have the same "carrying capacity" as one pipe of the larger size.

By "carrying capacity" is meant the amount of air carried, regardless of velocity, which will give the same loss in pressure due to friction per unit of length in each case.

The diameter of a round pipe to have the same carrying capacity as a rectangular pipe of dimensions A and B is given by the formula:

$$D = \sqrt[5]{\frac{32A^3B^3}{\pi^2(A+B)}}$$

The method usually followed in laying out factory work is as follows: Refer to the equalization table which is applicable for either round or square pipes, but not for both at the same time. This table gives the number of 1 inch pipes to equal in carrying capacity the various sizes given. Thus, if 1 – 12 inch pipe will carry a certain amount of air a certain distance with a certain loss of pressure due to friction, there would be required 501 – 1 inch pipes to carry the air the same distance with the same loss of pressure, or there would be required 501 ÷ 244 = 2 +, pipes each 9 inches diameter or say 1 – 9 inch pipe and 1 – 10 inch pipe.

Going back to the example and noting that the width of the housing is 57 per cent the diameter of the wheel: The outlet of 8-blade fans is usually made square with each dimension equal to the width of the housing. The fan has a wheel 8 feet = 96 inches diameter, × 57 per cent = 54 inches which is one side of the outlet, 54 inches × 54 inches = 2916 square inches = pipe 61 inches diameter.

Suppose the fan is set in the roof trusses near the center of the building and that is has two outlets, both the same size. From the equalization table 1 – 61 inch pipe = 29,000 – 1 inch pipes; 29,000 ÷ 2 = 14,500 – 1 inch pipes; 1 – 46 inch pipe = 1,562 square inches area = 31 inches x 54 inches, the size of each fan outlet.

The mains should be carried along the roof trusses and the air should be discharged about 3 feet above the floor. The branch pipes should be carried down along columns, etc., preferably 15 or 20 feet away from the outside walls and be discharged downward toward the floor and in the direction of the outside walls.

Assume it is convenient to take 15 outlets off each 46 inch main (which would be about the correct number making them about 20 feet apart). Each outlet would therefore be 14,500 ÷ 15 = 970 – 1 inch pipes = one 16 inch pipe for each branch. As to the size of mains, add the branches together according to the equalization table as the fan is approached. Thus, to carry three 16 inch pipes would require 970 × 3 = 2,910 – 1 inch pipes, which is equivalent on the equalization table to one 25 inch main.

By using the fifteen outlets each 16 inch diameter on each branch as obtained above, we would perhaps get 10 per cent more air out of the outlet nearest the fan than we would from the outlet furthest from the fan. This is not a serious error, and it would easily be taken care of by adjustments of the dampers; but to offset this, and to allow for a cooling of the air before it has reached its most distant outlet, it is usual to make the outlets larger as we get farther away from the fan. In this case, taking each 46 inch branch, starting from the center of the building and having fifteen outlets, instead of making them each 16 inches diameter we would make the four most distant from the fan about 17 inches diameter, the next six approaching the fan 16 inches diameter, and the five nearest the fan 15 inches diameter, adding the branches on the equalization table to get the mains.

The method just given is the one usually followed in factory work. There is so much uncertainty in this class of work that it seems unnecessary to attempt more refinements. The best advice in factory work is to get the fan large enough. If the heater is inadequate it is usually a simple matter to add an additional section or so of coil, or if you "fall down" on the duct system it is often a case of merely making extensions to the piping; and either item will cost little more after the system is installed than if put in with the balance of the work.

The most exact method consists in laying out a duct system with a certain loss of pressure due to friction, and then designing the fan to suit the conditions. Sufficient information on such a duct system is given in other parts of this book. Here follows the design of a fan, assuming that the duct system is as follows:

The longest run of duct is:

	Feet
One-half the length of building	= 160
One-half the width of building	= 50
Drop to floor	= 30
Total	= 240

Each fan outlet is 46 inches diameter = 1,662 square inches = $11\frac{1}{2}$ square feet. The amount of air through each outlet is 49,400 ÷ 2 = 24,700 *C.F.M.* Velocity in duct = 24,700 ÷ $11\frac{1}{2}$ square feet = 2,150 feet per minute = 36 feet per second.

As we are using a cone between fan inlet and heater, and have not sudden enlargements, we may neglect the entrance head, etc., and assume the static pressure to be composed entirely of friction.

A very safe formula for friction in ducts is as follows:

$$P = \frac{LV^2}{25{,}000D}, \text{ when}$$

P = loss of pressure in ounces per square inch.

L = length of galvanized iron duct in feet.

D = diameter of duct in inches.

Substituting D = 46 inch, L = 240 feet, and V = 36 feet, we have

$$P = \frac{240 \times 36 \times 36}{25{,}000 \times 46} = 0.25 \text{ oz.} = 0.46 \text{ inches w. g.}$$

This is the loss due to friction in ducts. The friction in 24 rows of 1 inch pipe coil at 1,250 feet velocity per minute = 0.65 w.g. The inlet of the 8-foot wheel would be 96 inches × 0.625 = 60 inches diameter = 19½ square feet. The velocity through inlet, which in this case represents the highest velocity in the system, = 49,400 ÷ 19½ = 2,400 feet per minute = 40 feet per second. The pressure necessary to create any velocity is given by the formula—

$$A.V.P. = \frac{V^2}{8\tfrac{1}{2}(t + 460)}, \text{ in which}$$

$A.V.P.$ = the pressure required in inches w.g.
v = the velocity per second to be created.
t = the temperature of the air handled.

Substituting in the formula above $V = 40$, $t = 130°$, we get—

$$A.V.P. = \frac{40 \times 40}{8\tfrac{1}{2}(130 + 460)} = 0.33 \text{ inches w.g.}$$

	Inches w.g.
Duct friction	0.46
Heater friction	0.65
A.V.P.	0.33
D.P. or dynamic pressure	1.44

As this is a "draw through" apparatus and the larger part of the resistance is on the inlet side, we will use the table for restricted inlet. $A.V.P. \div D.P. = 0.33 \div 1.44 = 23$ per cent. Refer to table and note that when this ratio is 23 per cent the following conditions will prevail:

A.V.P.÷P.V.P.	20
D.P.÷P.V.P.	86
S.P.÷P.V.P.	66
K_o=0.55, K_a=3.10, and M.E.	54

$P.V.P. = D.P. \div 86$ per cent $= 1.44 \div 86$ per cent $= 1.68$. Referring to the formula given before connecting pressure and velocity we get, transposing the formula for velocity:

Peripheral velocity = $\sqrt{8.5\,(130° + 460°) \times 1.68}$ = 92 feet per second = 5,500 feet per minute.

The formula for capacity given in the explanation of the table is $C.F.M. = \frac{WND^3\pi}{K_a}$, the symbols being there given. W in this case $= 0.4D$. Substituting, the formula becomes $C.F.M. = \frac{0.4ND^3\pi}{K_a}$

Now DN = peripheral velocity $\div \pi = 5{,}500 \div 3.1416 = 1.750$.

$$C.F.M. = \frac{0.4\pi D^2(1750)}{3.10} = \frac{2200D^2}{3.10} = 710D^2.$$

Therefore $D^2 = C.F.M. \div 710 = 49{,}400 \div 710 = 70$, and $D = \sqrt{70} = 8.3$ feet $= 100$ inches.

$$\text{Area inlet} = \frac{K_0Q}{\sqrt{DP}} = \frac{0.55 \times 49.4}{\sqrt{1.44}} = 22.65 \text{ square feet} = 3265 \text{ square}$$

inches = 64½ inches diameter. The standard inlet for 8-foot wheel is 59 inches diameter.

$N = 5{,}500 \div 8.3\pi = 211$ revolutions per minute.

Note that our former solution, which we might call approximate, gave us an 8-foot diameter wheel at 223 revolutions per minute, which, after all uncertain conditions are taken into account, is probably as nearly correct as this one.

Power required.

Brake $H.P.$ = Air $H.P. \div M.E.$

Air $H.P.$ = force in pounds x distance in feet per minute ÷ 33,000.

Now the distance in feet per minute = velocity per minute = $C.F.M.$ ÷ area of duct in square feet; and the force in pounds = area of duct in square feet × 144 × total pressure in inches w.g. ÷ (16 × 1.73). Therefore

$$B.H.P. = \frac{C.F.M. \times \text{area duct in square feet} \times 144 \times \text{total pressure}}{\text{area duct in square feet} \times 16 \times 1.73 \times 33{,}000 \times M.E.} =$$

$$\frac{C.F.M. \times \text{total pressure in inches w.g.}}{M.E. \times 6350}.$$ This is a general formula applicable to all kinds of fans, and in our particular case substituting $M.E.$ = 54 per cent, $C.F.M.$ = 49,400, and pressure = 1.44 inches w.g., we get:

$$B.H.P. = \frac{49400 \times 1.44}{6350 \times 0.54} = 21.$$

By "total pressure" above is meant not the peripheral velocity pressure, but the dynamic pressure.

SPECIAL REQUIREMENTS

Many kinds of buildings, by reason of the nature of the work carried on in them, or the more or less sedentary occupations of the employees, require special treatment.

Textile mills. Textile mills are generally heated from one side of the rooms. The heat flues are brought up in the outside walls, being plastered on the inside or lined with fire-clay flue lining. There is usually an abundance of exhaust steam for heating, but often a considerable quantity of the exhaust steam is used in the dye-rooms, etc. As a rule, the air should not be recirculated on account of the fine lint which fills it and the comparatively large number and sedentary positions of the operatives. About four air changes per hour gives the minimum amount of fresh air to be put into the rooms. The velocity of air in the vertical flues is usually about 900 feet per minute, and the velocity through the mill dampers should not exceed 400 feet per minute. Foul-air ducts are sometimes provided, but no exhaust fan is necessary.

Paper mills. In the machine rooms of paper mills the amount of air supplied should be about 100 per cent more than is required for the heating figured on a B.t.u. basis. This is on account of the large amount of moisture given off by the machines in the form of steam.

If all this vapor had to be absorbed by the air, the air quantities would be tremendous. There should be a hood over the machine, with an exhaust fan connected thereto, the object being to remove the steam before it has had a chance to condense. The capacity of this exhaust fan should be about 75 per cent of the total amount of air forced into the room. It is said that there are about two pounds of water evaporated for each pound of paper made, and that the capacity of an average machine is from one to one and a half tons of paper per hour. This, however, is a very general rule.

On account of the rapid deterioration of the galvanized iron ducts, they should be made out of iron two gauges heavier than the ordinary, should be soldered with as little punching and riveting as possible, and should be hung with copper or brass bands.

Foundries. In foundries a large amount of steam and other gases is given off during the pouring stage. Many of these gases are heavier than air and will not rise to the roof. There should be not less than three changes of fresh air per hour, but under suitable circumstances arrangements may be made for recirculating the air at times when no processes are going on to contaminate it. If possible an exhaust fan should be provided, and a disc fan will often answer this purpose.

The inlets to this exhaust fan should terminate in bell-shaped orifices about three feet above the floor line. The hot-air outlets should be about as in an ordinary factory job, about 15 or 20 feet above the floor. The above remarks apply to iron foundries. In some of the large brass foundries it seems simply impossible to get anything like satisfactory ventilation. The same system is about the best one for a brass foundry, but the air quantities should be at least three times that given above. The exhaust fan should in either case be of about the same capacity of the heating fan.

Distillery warehouses. In this class of buildings, on account of the high specific heat of the spirits which are constantly being removed and replaced by fresh goods, the heating proposition becomes somewhat special. Good practice is to increase the capacity of both fan and heater about 25 per cent over that required for the heating alone. This will usually give pretty close to four air changes per hour. Even then, starting up the apparatus when the weather is cold, it will be found that several days will be required to get the building and contents up to the temperature figured on.

The construction of such a building usually lends itself very admirably to heating. Generally parallel brick or concrete walls are built about four feet above the ground and about five feet apart for the full length of the building. These walls are used to support the racks in which the barrels are piled to the top of the building, sometimes forty feet or more high. There are usually about three aisles, one on either side and one in the center of the building. These aisles are open all the way to the top of the building and are the only portions of the building that are floored. The spaces under these aisles are used for hot-air ducts. They may have a concrete floor unless galvanized iron ducts are run in them. In any event the aisle floor just above, which is of wood, should be protected by a sheet of galvanized iron or bright tin. The air is admitted to the room through heavy cast-iron gratings placed in the floor of the outside aisles about 30 feet apart. These gratings must be extra-heavy, as a truck with a barrel of spirits will often pass over them; and they should have a suitable deflector placed in the duct below so that a correct distribution of air may be assured. Air is always recirculated as there is nothing whatever to contaminate it, the space under the center aisle being generally used for this purpose. Similar gratings are arranged in this aisle for removing the air, and the total area of gratings should be the same as the hot air gratings, which should allow an inlet velocity of, say, 500 feet per minute. The entire air system outside the building should be closed tight, and this recirculating duct should be carried back to the inlet of the heater coil. An exhaust fan system is very seldom necessary, as the ducts are usually large, owing to the construction of the building. The apparatus is usually placed in a separate building, and the system will be very simple and inexpensive if this building can be placed at the end of the warehouse so that the fan can draw air directly out of the recirculating duct, and a double discharge fan is used with one discharge going to each of the hot-air ducts. The ducts from fan to warehouse will of course be underground, and are constructed usually of brick or concrete. Exhaust steam is seldom available, and the general practice seems to be to use live steam on the coils at boiler pressure and return this condensation to the boiler in the most feasible manner. The engine exhaust is connected into a separate section of the coil and this condensation is returned to the boiler, through a separate return system.

Planing mills, etc. In woodworking plants in general there is usually ample exhaust steam, so that little would be gained in recirculating the air, except in cost of the heater. Often there are exhaust systems carrying out considerable quantities of air, and there is usually much opening and closing of large doors, and the construction of the building is often rather poor. At least as much fresh air should be put into the building as is carried out by any exhaust system.

Railroad round-houses. This is about the most uncertain class of buildings in regard to heating. The ventilation is quite a serious proposition, the locomotive doors are open half the time and often the locomotives have considerable snow on them to be thawed off before they can be inspected. These uncertainties put the round-house in the "guess" class.

Never less than ten air changes per hour should be allowed; always fresh air. The heating surface should be able to raise this amount of air from the outside temperature to about 140° which will require as a general rule about 300 to 400 square feet of heating surface per stall.

All hot air should be delivered through underground ducts into the locomotive pits. Sewer pipe laid in the usual manner may be used for the smaller size ducts. Ducts should be proportioned as previously explained. Velocity at outlets into pits should not be over 600 feet per minute. In the average round-house each pit will take four openings each 20 to 22 inches diameter. About one length of pipe may be used as an outlet and behind this an "increaser" should be used, for in "equalizing" the fan outlet it will generally be found that each of these outlets should be fed by a branch from the main about 15 inches or 16 inches diameter. A suitable adjustable blast-gate should be set in each outlet to be operated from inside the locomotive pit it supplies.

Ventilators, smoke-jacks, and the opening of doors will give ample means for the escape of air.

Apparatus is usually required to be outside the building, and when possible should be located near the center, on the outside of the round-house. In case of small round-houses the apparatus may be set at the end of the building, but it will often be found that with this arrangement there is not sufficient room for the main duct from the fan to pass between the footings of the outside wall and the locomotive pits.

Systems of exhaust ventilation. Systems of exhaust ventilation have been mentioned several times in connection with the heating question.

In many kinds of industrial works such as foundries, dye-houses, etc., gases are generated, often times heavier than air, which must be removed at once. This can be accomplished satisfactorily only by exhaust ventilation. Disc fans may be used for this purpose where the runs of ducts are short or no ducts at all are required.

When the offensive gases are local to the fixtures, as in dye-rooms, kitchens, etc., a hood suspended over the entire fixture the top of which is connected to the inlet of the exhaust fan is usually the best solution. Where the odors or gases are not local to any particular fixtures, as in a foundry, a system of bell-mouthed openings with inlets connected to the exhaust fan inlet will be found most effective.

As to the amount of air to be removed, judgment must be displayed. No definite rule can be given, except that the amount of air handled should be as great as conditions permit.

It is best not to blow air into kitchens, toilets, etc., from which offensive odors might find their way into other parts of the building, as with exhaust fan pulling on them there will be an inrush of air whenever a large opening into the room exists. If, however, such rooms are very large, as the kitchen in a large hotel, it may be necessary to blow some air into the room, but the capacity of the exhaust fan should be at least 25 per cent greater than that of the plenum fan.

Toilet-rooms. For a large number of fixtures local ventilation, supplemented by a register in the ceiling and another in the side wall near the floor, is a good arrangement. The local vent horns on closets are usually two to three inches in diameter. Connect each local vent full size, and add the pipes according to the equalization table.

In hotels and office buildings the private bath rooms are usually one above another on the various floors for convenience in making plumbing connections. In these rooms where there is but one closet it is not the custom to resort to local ventilation, but to place about 6 inch x 6 inch lock-face register in the wall just above the closet seat and connect this register in the wall to the main exhaust riser passing up the pipe shaft just behind. These various exhaust risers are collected at the attic and connected to the exhaust fan.

In fine work is it desirable to have a separate riser from each private bath room to the main gathering duct in the attic to prevent noises passing from one room to another, but this will often be found impossible for structural reasons.

Considerable care must be exercised in determining the size of ducts, as they will be somewhat small and the friction is liable to be excessive.

In local venting, an adjustable damper should be placed in the branch to each fixture and the closets should of course have no covers.

Kitchens, boiler rooms, etc. In kitchens, laundries, boiler rooms, etc., the foul air should be removed for the most part by hoods placed over the ranges, stoves, etc., and in front of the boilers.

When supplying air to such rooms some care must be exercised to see that a blast of relatively cold air is not blown directly towards a workman. If the system is to be used in winter it may be necessary to temper the air slightly. Serious lung affections are often the result of working in a blast of air which is cold compared to the air of the room, and as it feels refreshing, workmen are apt to run the risk.

The writer has observed that when fresh air is supplied to boiler-rooms, engine-rooms, kitchens, etc., it *must* be supplied near the floor and exhausted from the top of the room if the system is to be a success.

In hospitals, exhaust fans should in general be provided from kitchens, contagious wards, toilets, etc., and in the case of the contagious wards the duct from each room should be extended independently to the main gathering duct in the attic, so as to remove the remotest possibility of germ-laden air passing through the ventilating system into other rooms. Often electrically-controlled dampers are desirable in such ducts, arranged to close automatically if the fan stops for any reason. Such dampers when properly installed will prevent the transfer of air from one room to another under all circumstances.

THE PLENUM CHAMBER SYSTEM

This system is used almost universally in schools, hotels, etc., where the warming is done by hot air and continuous ventilation is desired.

The fans discharge into a large closed chamber which is divided by a horizontal partition into two portions, the upper portion being generally used for the hot air and the lower portion for the tempered air.

The cold air is usually taken from the top of the building by air shafts built for that purpose. Thence it passes through a tempering coil of sufficient capacity to raise the air to about 60°, if no washer is used. If an air washer is used the temperature should also be raised to about 60°; but the washer will reduce the temperature to about 45°, and another section of coil should be introduced to raise the air to about 60° before the air enters the fan, although this is not often done.

The use of bypass dampers is discussed under the subject of automatic temperature control.

Thence the air is drawn through the fan and forced over the heating coils. Under the heating coil is a bypass without a damper. The air which goes through the heater passes into the hot air portion of the plenum chamber, and that which goes through the bypass passes into the tempered air chamber. The temperature of the hot air chamber may vary from 100° to 140°, and that of the tempered air chamber from 45° to 70°.

There is a separate duct leading from this chamber to each room, or perhaps several ducts lead to a large room.

In each duct, at the plenum chamber, a set of mixing dampers are installed. Each duct has a full size connection to both the hot and tempered air portions of the plenum chamber, and the mixing dampers are so arranged that the sum of the openings from both portions of the plenum chamber into the duct shall remain the same; and the pressure in the two portions being practically equal (as a matter of fact the pressure in the tempered air portion is always a little greater than that in the hot air portion due to the friction in the heater coil) the same amount of air will flow regardless of the positions of the mixing dampers. These dampers are usually arranged to swing parallel with each other at all times. Each set of these mixing dampers is connected to a motor-valve which is operated by a thermostat located in the room supplied by the duct.

In addition to the mixing dampers which affect the temperature of air supplied but not its quantity, there is placed in each duct near the plenum chamber a volume damper, the object of which is to regulate the amount of air in each duct.

By-passes under heating and tempering coils are usually made about 50 per cent the free area of the coils above them.

School houses. The boilers operate as a rule on 30 to 40 lbs. pressure. The fan is usually driven by a direct-connected low-pressure engine operating on boiler pressure. This is decidedly the cheapest way of operating the engine, because the exhaust steam is used in the heater and it may be said that the steam to operate the engine costs nothing, for it is well known that exhaust steam is worth nearly as much for heating purposes as live steam. When electric power is to be purchased it is entirely possible for the electric current to cost as much as the steam to heat the air. The cost of the electric current is simply wasted, and that much might have been saved. Small vertical engines for driving fans are made today that are almost as near "fool proof" as an electric motor and requires as little attention.

The coils are fed direct from the boiler through a pressure-reducing valve. The engine exhaust passes through an oil separator into the low pressure side of the heating main. Steam pressure on the heater is about 2 to 3 pounds, or atmospheric.

The condensation is usually returned to the automatic feed pump and receiver by gravity and then to the boiler by the pump. Sometimes a system of return traps are used. In this case there is generally required one trap below the coils into which the water can drain by gravity, and a second trap on top of the boiler which receives the discharge from the first trap and returns the water to the boiler. The live steam connections to these return traps must be made from the high pressure side of the steam main.

Hotels, etc. Generally in buildings of this character there is a power plant in the basement, for operating generators, ice plant, pumps, etc., and fans are then usually driven by electric motors, direct-connected, and the heaters are supplied with steam from the exhaust of the various engines, pumps, etc. There is often a variety of uses for exhaust steam, and the pipe lines are long; and it will nearly always be found necessary to use some of the reliable mechanical vacuum systems.

Heaters and tempering coils. The heating and tempering coils, combined, are usually 16 to 24 rows of pipe deep or equivalent depth of cast-iron sections. The velocity is usually about 800 feet per minute.

Air shaft. The velocity in the air shaft should not exceed 600 feet per minute.

Ducts and flues. As a general rule ducts are figured for a velocity of 900 to 1,200 feet per minute and the vertical flues from 600 to 900 feet per minute.

Capacity and power of fans. Formulae for capacity and power of fans may be found under cases III and IV, depending upon which is applicable.

Foul air removal. For the removal of foul air vent ducts should always be provided. In schools and small office buildings vent rises the same size as the hot-air flues should be provided, leading directly to the attic where means of escape should be arranged, preferably by common ventilators of ample size. As a general rule it is not necessary to collect piping systems in the attic.

In hotels, large office buildings, club houses, etc., the runs of both heat and vent ducts are long and tortuous. It is usually the case that the foul air is removed through the basement and to the outside through exhaust flues provided for the purpose. In such cases the foul air ducts may as well be omitted if they are expected to remove the foul air without a special exhaust fan for the purpose. The subject of exhaust ventilation is hereinafter discussed.

The typical school-room is about 28 x 32 feet, and allowing one pupil for each 15 square feet of floor space (the general rule) and 30 C.F.M. to each pupil, we get 1,800 C.F.M. to each room. This requires 3 square feet of duct area, and at 300 feet velocity per minute 6 square feet of screen area. Often a cloak-room is just off the class-room and so located that a screen can be placed in the connecting door, allowing the warm air from the class-room to circulate through the cloak-room on its way to the foul-air duct, which has its inlet at the far end of the cloak-room. This warm air serves the double purpose of ventilating this room and drying the children's clothing.

Avoid such myths as gossamer checks, etc., as occupants of the rooms often imagine that they are getting no ventilation when these checks are closed (as they usually are), when as a matter of fact the air is escaping by more convenient channels than the foul air ducts.

Registers, grilles, etc. As a general rule wire screens made of about No. 12 wire, 1-inch diamond mesh, wired in $\frac{3}{4}$-inch channels, and the whole enameled black after being finished and in place, are used in school-rooms. These screens are cheap, present a neat appearance, offer the freest possible passage to the air, and (so desirable in school-room work) contain fewer corners in which dust can find lodgment than any other contrivance.

In office buildings, etc., register faces are generally used when the temperature is controlled automatically.

As a general rule the bottom of the hot-air outlets should be about 8 feet above the floor, blowing straight toward the exposed wall. The foul-air outlet should be at the floor line as nearly under the hot-air outlet as possible.

In hotel lobbies, cafés, etc., a system of exhaust outlets for summer use is usually desirable at the top of a room. The ducts from such outlets may be connected to the same exhaust fan as the other vents, and either set of vents may be used by a suitable arrangement of dampers.

Floor registers should usually be avoided, as they are extremely unsanitary. However, in school work it is a good plan to put a floor register about 48 inches x 60 inches or larger in each entrance hall as a "foot warmer."

THE DOUBLE DUCT SYSTEM

In this system, which has little to commend it, the plenum system is dispensed with and two ducts, a hot-air duct and a tempered-air duct, are carried to the base of each vertical flue. The arrangement of fan, heater, tempering coil, air washer, by-pass, etc., is exactly as explained for the plenum-chamber system. The air which goes through the heater passes into the hot-air duct, and the air which goes through the by-pass passes into the tempered-air duct. The hot-air duct, which is usually on top, is large enough to carry the entire amount of air; and the tempered-air duct is just below it and is about two-thirds the size of the hot-air duct.

The mixing dampers are installed at the base of each vertical flue, instead of at the plenum chamber as in the plenum-chamber system. These dampers regulate the temperature of the air delivered to the rooms, but not the quantity. To regulate the quantity the usual volume dampers are installed in both pipes of each branch from the main.

The pipes of the system are clumsily arranged and unwieldy. One of the double ducts should be on top of the other for convenience in making the double connections, and this often takes up too much headroom unless the ducts are made very shallow, which is objectionable. The dampers are scattered all over the building, and it is almost impossible to get this kind of a system into a complicated building, such as a hotel. It has, however, the advantage of permitting hand control of the temperature with continuous ventilation. This hand control is accomplished by having a suitable arrangement of levers extending down inside the air flue, and so arranged that the positions of the mixing dampers can be controlled from the various rooms. Of course this arrangement is possible only in buildings of the simplest construction. With the double duct system it is possible to use some of the inexpensive and effective systems of automatic temperature control, which, as hereinafter explained, are not applicable to the plenum-chamber system.

AUTOMATIC TEMPERATURE REGULATORS

For a plenum-chamber system the systems of automatic temperature control working through the agency of compressed air or electricity are the only practical ones, compressed air being preferable.

For a double duct system, where the mixing dampers are placed at the base of the vertical flues, some of the cheaper systems in which the mixing dampers are operated by a lever extending down from the thermostat in the room through the vertical flues to the mixing damper will probably give satisfaction, if proper care is given to the design of the levers and dampers.

In the pneumatic systems there are two kinds of thermostats, one operating the damper with a gradual motion backward and forward, seldom closing it off entirely, and another kind operating the damper with a so-called positive motion in which the damper is either entirely open or entirely closed. There are arguments for and against both systems.

Tempering coils. With the plenum chamber and double duct systems the tempering coils are controlled in the manner hereinbefore described, whether an air washer is used or not.

Heating coil. As a general rule, automatic control is not provided on heating coils, the sections being separately valved for hand control.

Mixing dampers. These dampers are controlled by thermostats in the various rooms, one thermostat to a room being ordinarily all that is required. The thermostats should be of a type that will operate the dampers with a graduated or gradually-moving motion.

Cloth filters. Cloth filters are inefficient, and have greater resistance than is generally supposed, and their use should be discouraged. The writer recently observed a case where a *new*, *clean* filter of the texture of ordinary cheese-cloth was in use, and a velocity of 1 foot per second through same reduced the capacity of the fan exactly 25 per cent, all other conditions remaining the same during both tests.

AMOUNT OF AIR FOR VENTILATION

The following table represents good practice as to the amount of air required for the ventilation of various classes of buildings:

Hospitals	50 to 75 cubic feet per minute per occupant
High Schools	30 cubic feet per minute per occupant
College class-rooms	25 cubic feet per minute per occupant
Theatres, etc.	25 cubic feet per minute per occupant
Churches	20 cubic feet per minute per occupant
Public waiting-rooms	4 air changes per hour
Public toilet-rooms	10 air changes per hour
Locker rooms	6 air changes per hour
Small convention-hall	4 air changes per hour
Public offices	3 air changes per hour
Private offices	4 air changes per hour

Ball-rooms	4 air changes per hour
Public dining-halls	4 air changes per hour
Banquet halls	5 air changes per hour
Public libraries	3 air changes per hour
Private libraries	4 air changes per hour
Railroad round-houses	12 air changes per hour
Textile mills	4 air changes per hour
Foundries	3 air changes per hour
Hotel lobbies	4 air changes per hour
Hotel kitchens	4 to 6 air changes per hour
Boiler-rooms	2 to 6 air changes per hour
Engine-rooms	3 to 6 air changes per hour

When it is desired to keep the air in a room at a certain standard of purity, which is usually expressed in so many parts of CO_2 per 10,000 parts of air by volume, the amount of air to accomplish this may be estimated as follows:

It is always necessary to make an assumption as to the amount of CO_2 in the outside air. This is usually taken as 4 parts in 10,000.

a = number parts of CO_2 allowable in the air of room.
b = number parts of CO_2 in external air.
C = cubic feet of CO_2 per hour to be dissipated.

Cubic feet of fresh air per hour $= \mathrm{C} \div (a - b) \div 10{,}000$.

a = about $7\frac{1}{2}$ in schools.
b = about 4 in ordinary external air.
C = about 0.6 cubic foot per hour per person.

RELATIVE TEMPERATURES

In contract work a guarantee is generally required that the plant will heat the building to a certain temperature when the outside temperature is a certain degree. As it is usually inconvenient to postpone the final tests until the low outside temperature named in the guarantee is reached, it is desirable to have some means of arriving at results with outside temperature above that point. When the plant is tested, if it meets the guarantee, the resulting temperature in the rooms will be equal to or greater than t_2 given by the following formula:

$t_2 = [T\,(T - t_1) + t_3\,(\mathrm{T} - t)] \div (T - t_1)$, when

t = inside temperature named in the guarantee.
t_1 = outside temperature named in the guarantee.
t_2 = inside temperature maintained during test.
t_3 = outside temperature during test.
T = temperature of steam or water assumed to be the same in test as in guarantee.

The accuracy of the above formula depends on the following. The heat losses from the building are in direct proportion to the temperature difference inside and outside; the condensation from direct radiation is proportional to the difference in temperature of steam or water in the coil and that of the room; and in cases of indirect or blast coils the condensation is proportional to the difference in temperature of steam or water in the coil and that of the entering air.

There has been considerable argument recently as to the correctness of the above hypotheses, without advancing any that are more reasonable.

One reason for a plant in a newly constructed building failing to produce the expected temperature may be that so large a part of the heat given off by the coils is taken up in drying out the brickwork, etc. This is especially noteworthy in concrete buildings.

In making the test the boilers should be run on the guaranteed pressure; and in case of fan work the dampers should be set to give the predetermined distribution of air and the fan should be run at the specified speed with all vent ducts open.

COSTS

The following table gives figures by which a rough preliminary estimate may be made of the approximate cost of a job. All apparatus given is erected complete.

Steel plate fans:
- 1¼ cents per C.F.M. for factories with foundations.
- 1½ cents per C.F.M. for schools, etc., with foundations.

Engines (direct-connected):
- 1 cent per C.F.M. for factories including foundations.
- 1½ cents per C.F.M. for schools, etc., including foundations.
- Plenum chambers, ¾ to 1 cent per C.F.M.
- Heating surface (iron pipe or cast iron), 40 cents per square foot of surface.
- Galvanized iron work, 10 to 12 cents per pound.
- Registers, 1⅔ cents per C.F.M.
- Register faces, 1 cent per C.F.M.
- Boilers and piping, $1.50 per square foot indirect surface, and 50 cents per square foot direct surface.
- Miscellaneous steam specialties, 2 cents per C.F.M.
- Contractor's profit and miscellaneous expenditures, add one-third of total of above.

PROPERTIES OF FANS

The object of discussing this subject is not to advocate special fans, but to enable the engineer to choose a fan to do a certain work when the conditions are known, but are too far out of the ordinary to permit the use of the general formulae given in other parts of this book.

An example will be given for each style of fan discussed, and a different set of conditions will be assumed in each case to illustrate the elasticity of the tables.

Steel plate fans. These are the ordinary type of eight or ten-blade fans, in which:

Diameter of inlet = 0.61 diameter of wheel.
Width of periphery = 0.40 diameter of wheel.
Width of housing = 0.54 diameter of wheel.

In the following table the symbols are as follows:

A.V.P. = pressure due to actual velocity of air at inlet or outlet, called "air velocity pressure."

S.P. = total friction loss in entire system, i.e., heater, washer, ducts, etc., called "static pressure." This must also include all loss of pressure due to any cause, as sudden enlargement in ducts, entrance head, etc. This entrance head is not always easy to estimate. An open pipe of short length placed in the outlet of a fan will show practically no static pressure, but place the same pipe on the inlet of the fan and a considerable static vacuum will be found, which is the entrance head. This head depends, of course, on size of pipe, velocity of air flow, and the condition of the free end of the pipe. A cone in the end will reduce this head and increase the air flow, etc. Each case in this respect will have to be figured out on its own merits, reference being had to the various handbooks which contain data not necessary or desirable to reproduce here. In the tables based on free inlets and restricted outlets, the entrance head into the inlet is not to be considered, as it has been taken account of in the tables.

D.P. = dynamic or total pressure = *A.V.P.* plus *S.P.*

M.E. = mechanical efficiency.

P.V.P. = pressure due to velocity of air if it is moving at same velocity as fan tips, called "peripheral velocity pressure."

All pressures are in inches water gauge. The "ratio of opening" is in fact an arbitrary term. Experimentally, it is the ratio of the area of a circular opening in a flat plate close to the fan, and through which it discharges, to the area of fan outlet.

K_a = constant for blast area.
K_o = constant for orifice to be used in the following formulae:

$$\text{Area inlet} = \frac{K_oQ}{\sqrt{DP}}; \; B_a = \frac{DW}{K_a}; \text{ and } C.F.M. = \frac{\pi ND^2W}{K_a}, \text{ in which}$$

D = diameter of wheel in feet.
W = width of periphery in feet.
N = revolutions per minute.
$C.F.M.$ = cubic feet of air per minute.
Q = $C.F.M. \div 1{,}000$.

Pressure of air due to any velocity is

$$A.V.P. = \frac{\text{Barometer} \times V^2}{253\,(460 + t)}, \text{ when}$$

V = velocity in feet per second, and
t = temperature of air.

For a barometer of 29.92 inches mercury, the formula becomes

$$A.V.P. = \frac{V^2}{8\frac{1}{2}(460 + t)}.$$

Ratio of opening	$\frac{\text{A.V.P.}}{\text{D.P.}}$	$\frac{\text{A.V.P.}}{\text{P.V.P.}}$	$\frac{\text{S.P.}}{\text{P.V.P.}}$	$\frac{\text{D.P.}}{\text{P.V.P.}}$	M.E.	K_a	K_o
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*		
0	0	0	117	117	0		
10	1	1	116	117	15		
20	2	1.5	114	115.5	26	11.3	2.[illegible]
30	4	3.5	109	112.5	35	7.5	1.[illegible]
40	7	6	102	108	40	5.7	1.10
50	11	10	91	101	43	4.5	0.87
60	15	13	78	91	45	3.8	0.70
70	21	17	63	80	41	3.2	0.55
80	32	23	44	67	38	2.9	0.46
90	52	28	23	51	31	2.6	0.[illegible]
100	100	33	0	33	2[illegible]	2.5	0.[illegible]

The above table is based on free inlet and all restriction on the outlet side. The "entrance head" into fan inlet is not to be considered in using this table.

For example: Assume we had a heating system in which the total friction loss, etc., in heater, washer, ducts, etc., is 1 inch water, and that we fix 5,000 feet per minute as the velocity of fan tips. $C.F.M. = 25{,}000$ at 70°, peripheral velocity in feet per second $= 5{,}000 \div 60 = 83.3$, and

$$P.V.P. = \frac{83.3^2}{8\tfrac{1}{2}\,(460 + 70)} = 1.54 \text{ inches.}$$

Now $S.P. \div P.V.P. = 1.00 \div 1.54 = 65$ per cent; when this ratio exists, by interpolation in the above table we get: Ratio opening $= 69$ per cent; $A.V.P. \div D.P. = 20$ per cent; $A.V.P. \div P.V.P. = 16$ per cent; $D.P. \div P.V.P. = 83$ per cent; $M.E. = 41$ per cent; $K_a = 3.3$; and $K_o = 0.56$. Since we fixed the peripheral velocity at 5,000 feet per minute, $\pi DN = 5{,}000$, and since $C.F.M. = \frac{\pi N D^2 W}{K}$, we have $DW = \frac{C.F.M. \times K_a}{5{,}000} = \frac{25{,}000 \times 3.3}{5{,}000} = 16.5$, and now, since the usual proportions are $W = 0.4\,D$, we get $0.4\,D^2 = 16.5$, or $D^2 = 41.25$, and $D = 6.43$ feet $= 77$ inches. Use a $6\tfrac{1}{2}$-foot diameter wheel, as this is a standard size, and $W = 16.5 \div D = 2.54$ feet $= 30\tfrac{1}{2}$ inches. Now $D.P. = 0.83\ P.V.P. = 0.83 \times 1.54 = 1.28$ inches water, and area inlet $= \frac{K_oQ}{\sqrt{D.P.}} = \frac{0.56 \times 25}{\sqrt{1.28}} = 12.4$ square feet $= 1{,}780$ square inches $= 47\tfrac{1}{2}$ inches diameter, and outlet $= 1{,}780$ square inches $= 42$ inches $\times$ 42 inches.

The brake horse-power is

$$B.H.P. = \frac{5.2 \times D.P. \times C.F.M.}{33{,}000 \times M.E.} = \frac{5.2 \times 1.28 \times 25{,}000}{33{,}000 \times 0.41} = 12.3.$$

Check inlet by $A.V.P. = 0.16\,P.V.P. = 0.16 \times 1.54 = 0.246$ inch, and the velocity to give this pressure is: Velocity $= \sqrt{0.246 \times (460 + 70) \times 8\tfrac{1}{2}} = 33.3$ feet per second $= 2{,}000$ feet per minute, which, divided into the 25,000 $C.F.M.$, gives 12.5 square feet against 12.4 square feet by the other method. Either will be correct.

N can, of course, be figured by $\pi DN = 5{,}000$ and $N = 5{,}000 \div \pi D = 5{,}000 \div 6\tfrac{1}{2}\,\pi = 245$ turns per minute.

The following table has been calculated from a careful test on several 8-blade fans with the outlet practically free and the restriction placed in the fan inlet. It simply means, when compared with the foregoing table, that a given fan will handle more air through a given orifice on the inlet side than it will if the same orifice is on the outlet.

Ratio inlet opening	K_a	$\frac{A.V.P.}{P.V.P.}$	$\frac{A.V.P.}{D.P.}$	$\frac{D.P.}{P.V.P.}$	$\frac{S.P.}{P.V.P.}$	M.E.	K_o
Per cent		*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	
0		0	0		0	0	
10	11.60	1.5	1	150	149	37	2.75
20	6.00	5.0	5	100	95	51	1.16
30	4.55	9.0	11	81	72	54	0.79
40	3.75	13.0	18	72	59	55	0.61
50	3.10	20.0	23	86	66	54	0.55
60	2.80	24.0	27	89	65	53	0.51
70	2.55	29.0	31	94	65	53	0.48
80	2.45	32.0	34	95	63	53	0.46
90	2.35	34.0	35	97	63	52	0.45
100	2.30	36.0	36	100	64	52	0.44

Assume that it is desired to exhaust 25,000 *C.F.M.* through a set of orifices and a pipe in which the friction loss in the pipe plus the static head necessary to be maintained just inside the orifices is 1.1 inches water, and to discharge it into free air at 70° temperature; fan to run at about 5,000 feet per minute.

Velocity, 5,000 ÷ 60 = 83.13 feet per second, and

$$P.V.P. = \frac{(83.3)^2}{8\frac{1}{2}(460+70)} = 1.54 \text{ inches;}$$

and now $S.P. \div P.V.P. = 1.10 \div 1.54 = 72$ per cent, and referring to table above, note that: Ratio opening = 30 per cent; $K_a = 4.55$; $A.V.P. \div D.P. = 11$ per cent; $A.V.P. \div P.V.P. = 19$ per cent; $D.P. \div P.V.P. = 81$ per cent; $M.E. = 54$; $K_o = 0.79$.

Area inlet $= \dfrac{K_oQ}{\sqrt{D.P.}} = \dfrac{0.79 \times 25}{\sqrt{1.25}} = 17.6$ square feet = 2,540 square inches = 57 inches diameter; the *D.P.*, being 81 per cent of $P.V.P. = 0.81 \times 1.54 = 1.25$ inches.

Check inlet by $A.V.P. = 0.11\ D.P. = 0.11 \times 1.25 = 0.137$, and air velocity $= \sqrt{0.137 \times 8\frac{1}{2} \times 530} = 24$ feet per second = 1,440 feet per minute. 25,000 ÷ 1,440 = 17.4 square feet = 2,510 square inches = 56½ inches diameter, which is a good check.

Assume wheel to be $D = 57 \div 0.61 = 94$ inches = 7.83 feet, say 8 feet, and $N = 5{,}000 \div 8\pi = 200$. From the formula

$$C.F.M. = \frac{\pi N D^2 W}{K_a}, \text{ we get}$$

$$W = \frac{C.F.M. \times K_a}{\pi N D^2} = \frac{25{,}000 \times 4.55}{5{,}000 \times 8} = 2.85 \text{ feet} = 34 \text{ inches.}$$

$$B.H.P. = \frac{5.2 \times D.P. \times C.F.M.}{33{,}000 \times M.E.} = \frac{5.2 \times 1.25 \times 25{,}000}{33{,}000 \times 0.54} = 9.2.$$

In the design of 8-blade fans it should be remembered that if the diameter of the inlet is more than two-thirds the diameter of the wheel, the blades may be too shallow for maximum efficiency; therefore the standard proportions should be adhered to as closely as possible.

Arbitrarily varying the width of the periphery without corresponding change in size of inlet and outlet will affect the performance but little, so long as the discharge area of the wheel (i.e., πDW) is greater than the inlet or outlet area, which is usually the case.

Double-inlet 8-blade fans are constructed in two ways as regards their performance with reference to single-inlet fans, discussed heretofore. The first method is as follows: If a double-inlet fan is to be designed to handle a given amount of air against a given pressure, a fan is designed and speed, horse-power, wheel, etc., determined for a single-inlet fan to handle one-half the amount of air at the given pressure; and then the width of periphery is doubled, size of outlet is doubled, and width of housing is increased by an amount equal to the increase in periphery. At the same speed the fan will handle twice the amount of air handled by the single-inlet fan, and will require practically twice the power.

The second method is to design a single-inlet fan to deliver 71 per cent of the volume of air required at one-half the static pressure or friction loss, and then, without changing any dimensions of the fan (except adding another inlet of same size) it will do the work required without change of speed, and the power will be three times that estimated for the single-inlet fan. This based on a theory, borne out by experiment, that two inlets, without any other change in fan or so-called "ratio of opening," will increase the capacity of $\sqrt{2}$ as a multiple, and as the pressure varies as the square of the velocity, this will be doubled, and further, since the horse-power varies as the product of capacity and pressure it will be increased by $2 \times 1.41 = 2.82$ as a multiple, but as there is some loss in efficiency we will call this factor 3.

The capacity of an 8-blade fan at same speed and same ratio of opening varies about as the cube of the inlet diameter; therefore, to make a double-inlet fan to do the same work as a given single-inlet fan, we have merely to divide the diameter of inlet by $\sqrt{2}$ and use two inlets instead of one.

In selecting motors or engines for driving fans it is always well to be liberal as to sizes.

Cone fans. The following table gives the properties of the ordinary type of 8-blade cone fan. The usual proportions are: $W = 0.25\ D$, and diameter of inlet $= 0.75\ D$. This table is based on free outlet and a vacuum chamber on inlet side in which *S.P.* is the total static vacuum in chamber necessary to overcome friction, entrance head, etc.

Ratio of opening	$\frac{\text{A.V.P.}}{\text{D.P.}}$	$\frac{\text{A.V.P.}}{\text{P.V.P.}}$	$\frac{\text{S.P.}}{\text{P.V.P.}}$	$\frac{\text{D.P.}}{\text{P.V.P.}}$	M.E.	K_a	K_o
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*		
0	0	0	88	88	0		
10	3	2	77	79	37		
20	6	4	69	73	43	2.9	1.15
30	9	6	64	70	46	2.3	0.90
40	13	11	58	69	48	1.7	0.66
50	17	14	54	68	49	1.5	0.58
60	22	19	49	68	50	1.3	0.51
70	28	22	45	67	50	1.2	0.46
80	34	24	41	65	50	1.15	0.44
90	39	26	38	64	50	1.1	0.42
100	45	29	34	63	50	1.0	0.38

Assume we were exhausting 15,000 *C.F.M.* through a 36-inch diameter pipe in which the friction loss and entrance head are estimated to be 0.50 inch water. Temperature of air 70°. Suppose we wanted to use a fan to run at a peripheral velocity of about 4,400 feet per minute = 73½ feet per second.

$$P.V.P = \frac{(73.5)^2}{8\frac{1}{2} \times 530} = 1.20 \text{ inches.}$$

Now *S.P.* ÷ *P.V.P.* = 0.50 ÷ 1.2 = 0.42 per cent, and from the table we find: Ratio of opening = 77½ per cent; *A.V.P.* ÷ *D.P.* = 33 per cent; *A.V.P.* ÷ *P.V.P.* = 23½ per cent; *D.P.* ÷ *P.V.P* = 65½ per cent; *M.E.* = 50 per cent; K_a = 1.16; and K_o = 0.44.

$$\text{From } C.F.M. = \frac{\pi N D^2 W}{K_a} \text{ we get}$$

$$DW = \frac{C.F.M. \times K}{\pi N D} = \frac{15{,}000 \times 1.16}{4400} = 3.96, \text{ and since } W = 0.25D,$$

we get $D^2 = 3.96 \div 0.25 = 15.8$, and D = say 4 feet.

Now *D.P.* = 65½ per cent *P.V.P* = 0.655 × 1.2 = 0.78 inch; and *A.V.P.* = 23½ per cent *P.V.P.* = 0.235 × 1.2 = 0.28 inch.

$$B.H.P. = \frac{5.2 \times D.P. \times C.F.M.}{33{,}000 \times M.E.} = \frac{5.2 \times 0.78 \times 15{,}000}{33{,}000 \times 0.50} = 3.7$$

$$\text{Area inlet} = \frac{K_o Q}{\sqrt{D.P.}} = \frac{0.44 \times 15}{\sqrt{0.78}} = 7.2 \text{ square feet} = 1040 \text{ square}$$

inches = 36½ inches diameter.

Check inlet by air velocity $= \sqrt{A.V.P. \times 8\frac{1}{2} \times 530} = \sqrt{0.28 \times 8\frac{1}{2} \times 530}$ $= 35.4$ feet per second $= 2{,}125$ feet per minute, which, divided into $15{,}000 = 7.1$ square feet $= 1{,}020$ square inches $= 36$ inches diameter against $36\frac{1}{2}$ inches above. Use 36-inch diameter inlet, 48-inch diameter fan, 12 inches wide, and $R.P.M. = 4{,}400 \div 4\,\pi = 350$.

The following table is given for same type of cone fan as above, except that all resistance is on the outlet, as for a fan drawing free air and discharging into a plenum chamber, the *S.P.* being the static pressure in plenum chamber to overcome friction, entrance head, etc. The ratio of opening is with respect to the inlet. All symbols the same as before.

Ratio of opening	$\frac{A.V.P.}{D.P.}$	$\frac{A.V.P.}{P.V.P.}$	$\frac{S.P.}{P.V.P.}$	$\frac{D.P.}{P.V.P.}$	M.E.	K_a	K_o
Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*		
0	0	0	105	105	0		
10	2	2	91	93	51	3.9	
20	5	3.5	79	82.5	49	3.0	1.28
30	7	5	69	74	43	2.5	1.00
40	11	6.5	59	65.5	39	2.2	0.82
50	14	8	52	60	36	2.0	0.72
60	17	10	46	56	34	1.8	0.63
70	21	11	42	53	33	1.7	0.58
80	23	12	38	50	32	1.6	0.53
90	24	12	35	47	31	1.6	0.51
100	26	13	31	44	31	1.6	0.50

Assume we had a heater, ducts, etc., on the outlet of fan in which friction loss and entrance head had been estimated at 1 inch water, 20,000 *C.F.M.* at 0^{0}. What size fan is to be used if the peripheral velocity is to be 6,000 feet per minute, or 100 feet per second?

$$P.V.P. = \frac{(100)^2}{8\frac{1}{2}\,(460)} = 2.56 \text{ inches, and } \frac{S.P.}{P.V.P.} = \frac{1.00}{2.56} = 39 \text{ per cent.}$$

Refer to the table, and note that: Ratio of opening = 78 per cent; $A.V.P. \div D.P. = 23$ per cent; $A.V.P. \div P.V.P. = 12$ per cent; $D.P. \div P.V.P. = 51$ per cent; $M.E. = 32$ per cent; $K_a = 1.6$.; and $K_o = 0.54$.

$A.V.P. = P.V.P. \times 0.12 = 0.12 \times 2.56 = 0.308$ inch; and air velocity $= \sqrt{0.308 \times 8\frac{1}{2} \times 460} = 34.6$ feet per second $= 2{,}175$ feet per minute; $20{,}000 \div 2{,}175 = 9.2$ square feet $= 1{,}325$ square inches = 42-inch diameter inlet.

Check inlet by the formula, Area inlet $= \frac{K_oQ}{\sqrt{D.P.}} = \frac{0.54 \times 20}{\sqrt{1.31}} = 9.25$ square feet $= 1{,}335$ square inches = 42-inch diameter inlet.

The $D.P.$ being 51 per cent of $P.V.P. = 0.51 \times 2.56 = 1.31$ inches. Since $\pi DN = 6{,}000$, we may find DW by the formula, $\pi ND^2W = C.F.M. \times K_a$, from which we get, $DW = \dfrac{C.F.M. \times K_a}{\pi ND} = \dfrac{20{,}000 \times 1.6}{6000} = 5.33$; and since $W = \dfrac{D}{4}$ we get $\dfrac{D^2}{4} = 5.33$, or $D^2 = 21.3$, and $D = 4.6$ feet $= 55$ inches.

Make $D = 54$ inches, and 42-inch diameter inlet. $N = 6000 \div \pi D = 6000 \div (\pi \times 4\frac{1}{2}) = 425$ revolutions per minute.

$$B.H.P. = \frac{5.2 \times D.P. \times C.F.M.}{33{,}000 \times M.E.} = \frac{5.2 \times 1.31 \times 20{,}000}{33{,}000 \times 0.32} = 13.$$

"Sirocco" fans. The following tables give the properties of "Sirocco" fans under different conditions of outlet restriction.

The symbols are as follows:

$A.V.P.$ = air velocity pressure at fan outlet.
$S.P.$ = static pressure = total friction loss plus loss of pressure due to any other cause.
$D.P.$ = dynamic or total pressure = $A.V.P. + S.P.$
$M.E.$ = mechanical efficiency.

All pressures are in inches water.

The ratio of opening is with respect to the fan outlet. Temperature of air handled is 62° F. The standard proportions of "Sirocco" fans are: Width of periphery = one-half diameter of wheel, outlet is square and each side = two-thirds diameter of wheel, the diameter of inlet in the casing is 1 inch to 2 inches larger than the wheel, tapering in a cone to the inlet in wheel, which is equal to the diameter of the wheel less the depth of the blades.

Ratio opening	$\frac{A.V.P.}{D.P.}$	Mechanical Efficiency		DYNAMIC OR TOTAL PRESSURE-INCHES WATER										
				0.25	0.375	0.50	0.625	0.75	0.875	1.00	1.25	1.50	1.75	2.00
Per cent														
100	1.000	0.528	C.F.M.	2,000	2,450	2,830	3,164	3,467	3,744	4,000	4,475	4,903	5,295	5,660
			S.P.	0	0	0	0	0	0	0	0	0	0	0
			R.P.M.	303	371	428	478	525	567	605	677	741	[illegible]	864
			B.H.P.	0.149	0.274	0.422	0.591	0.776	0.979	1.193	1.677	2.195	2.797	3.482
95	0.802	0.555	C.F.M.	1790	2194	2534	2836	3105	3352	3585	4013	4390	4740	5068
			S.P.	0.050	0.074	0.099	0.124	0.149	0.173	0.198	0.248	0.297	0.347	0.396
			R.P.M.	296	363	419	469	513	554	592	661	725	784	[illegible]
			B.H.P.	0.127	0.233	0.360	0.503	0.661	0.832	1.017	1.423	[illegible]	[illegible]	2.875
90	0.647	0.578	C.F.M.	1609	1970	2275	2544	2788	3010	3218	3506	3940	4256	[illegible]
			S.P.	0.088	0.133	0.177	0.221	0.265	0.309	0.353	0.441	0.530	0.618	0.707
			R.P.M.	292	357	413	461	506	546	581	653	710	773	826
			B.H.P.	0.110	0.201	0.310	0.434	0.570	0.718	0.878	1.225	1.619	[illegible]	2.480

Ratio opening	A.V.P. / D.P.	Mechanical Efficiency		DYNAMIC OR TOTAL PRESSURE-INCHES WATER										
Per cent				0.25	0.375	0.50	0.625	0.75	0.875	1.00	1.25	1.50	1.75	2.00
85	0.526	0.590	C.F.M.	1451	1777	2050	2295	2512	2715	2900	3243	3555	3840	4105
			S.P.	0.118	0.178	0.237	0.296	0.355	0.415	0.474	0.592	0.711	0.829	0.948
			R.P.M.	290	355	410	458	502	541	579	648	710	766	819
			B.H.P.	0.097	0.178	0.274	0.383	0.503	0.634	0.775	1.082	1.423	1.794	2.191
80	0.426	0.595	C.F.M.	1305	1597	1845	2063	2258	2440	2610	2920	3195	3450	3690
			S.P.	0.144	0.216	0.268	0.359	0.431	0.503	0.575	0.718	0.862	1.006	1.150
			R.P.M.	288	353	407	455	499	539	576	644	706	762	814
			B.H.P.	0.086	0.159	0.245	0.342	0.448	0.566	0.692	0.967	1.27	1.599	1.955
75	0.347	0.590	C.F.M.	1179	1442	1666	1863	2040	2205	2358	2635	2888	3120	3335
			S.P.	0.163	0.245	0.327	0.408	0.490	0.572	0.653	0.816	0.980	1.143	1.306
			R.P.M.	288	353	407	455	499	539	575	644	705	762	814
			B.H.P.	0.079	0.144	0.222	0.311	0.408	0.515	0.630	0.880	1.157	1.458	1.780
70	0.287	0.581	C.F.M.	1071	1312	1515	1693	1855	2005	2143	2395	2625	2840	3030
			S.P.	0.178	0.268	0.357	0.446	0.535	0.624	0.713	0.891	1.07	1.248	1.426
			R.P.M.	290	355	410	459	502	542	580	649	709	766	819
			B.H.P.	0.073	0.133	0.205	0.287	0.377	0.476	0.581	0.812	1.068	1.348	1.643
65	0.240	0.567	C.F.M.	980	1200	1386	1550	1698	1833	1960	2192	2402	2593	2773
			S.P.	0.190	0.285	0.380	0.475	0.570	0.665	0.76	0.95	1.14	1.33	1.52
			R.P.M.	293	359	414	463	507	548	586	655	718	775	828
			B.H.P.	0.068	0.125	0.193	0.269	0.354	0.446	0.545	0.761	1.001	1.26	1.539
60	0.200	0.548	C.F.M.	895	1096	1265	1414	1550	1674	1790	2000	2193	2367	2530
			S.P.	0.20	0.30	0.40	0.50	0.60	0.70	0.80	1.00	1.20	1.40	1.60
			R.P.M.	298	364	421	471	516	557	595	665	729	788	842
			B.H.P.	0.064	0.118	0.182	0.254	0.334	0.421	0.515	0.719	0.946	1.19	1.454
55	0.165	0.531	C.F.M.	813	996	1150	1285	1408	1520	1625	1818	1990	2150	2300
			S.P.	0.209	0.313	0.417	0.522	0.626	0.731	0.835	1.044	1.253	1.461	1.670
			R.P.M.	302	371	428	479	525	566	605	677	741	800	855
			B.H.P.	0.06	0.111	0.171	0.238	0.313	0.395	0.482	0.674	0.887	1.116	1.365
50	0.133	0.517	C.F.M.	729	892	1030	1151	1261	1361	1457	1628	1783	1927	2060
			S.P.	0.217	0.325	0.434	0.542	0.651	0.759	0.868	1.084	1.301	1.518	1.735
			R.P.M.	305	373	431	482	528	570	609	681	747	807	862
			B.H.P.	0.055	0.102	0.157	0.219	0.288	0.363	0.444	0.620	0.815	1.026	1.254
45	0.103	0.503	C.F.M.	643	787	910	1015	1112	1202	1285	1435	1572	1700	1818
			S.P.	0.224	0.336	0.448	0.561	0.673	0.785	0.897	1.121	1.345	1.57	1.794
			R.P.M.	305	373	431	482	529	550	610	681	748	807	863
			B.H.P.	0.050	0.093	0.142	0.199	0.261	0.33	0.402	0.562	0.740	0.903	1.139
40	0.080	0.490	C.F.M.	566	694	800	895	981	1059	1131	1265	1386	1497	1600
			S.P.	0.23	0.345	0.460	0.575	0.690	0.805	0.920	1.150	1.380	1.610	1.840
			R.P.M.	304	372	430	481	526	569	609	681	745	805	860
			B.H.P.	0.046	0.084	0.129	0.180	0.237	0.298	0.364	0.509	0.669	0.843	1.029
30	0.046	0.451	C.F.M.	426	523	604	675	740	799	854	955	1046	1129	1209
			S.P.	0.239	0.358	0.477	0.597	0.716	0.835	0.955	1.193	1.432	1.670	1.909
			R.P.M.	298	366	423	472	513	559	597	668	732	790	845
			B.H.P.	0.037	0.069	0.105	0.147	0.194	0.244	0.298	0.417	0.548	0.689	0.844
20	0.021	0.352	C.F.M.	290	355	410	458	502	543	580	649	711	768	820
			S.P.	0.245	0.367	0.490	0.612	0.734	0.857	0.979	1.224	1.468	1.713	1.958
			R.P.M.	288	353	407	455	499	539	575	644	705	762	814
			B.H.P.	0.032	0.060	0.092	0.128	0.169	0.213	0.260	0.363	0.478	0.602	0.734
10	0.007	0.212	C.F.M.	167	205	237	265	290	313	335	374	410	443	480
			S.P.	0.248	0.372	0.497	0.621	0.745	0.869	0.993	1.241	1.490	1.738	1.986
			R.P.M.	273	334	386	432	473	511	546	610	670	723	773
			B.H.P.	0.031	0.057	0.088	0.123	0.162	0.204	0.249	0.348	0.457	0.576	0.714

The following table gives certain factors varying with size of fan wheel.

Wheel		Volume and B.H.P. Constant	R.P.M. Constant	Size of Outlet
Number	Diameter			
	Inches			inches
½	3	0.0278	6.00	2x2
¾	4½	0.0625	4.00	3x3
1	6	0.1111	3.00	4x4
1¼	7½	0.1736	2.40	5x5
1½	9	0.2500	2.00	6x6
1¾	10½	0.3403	1.714	7x7
2	12	0.4444	1.500	8x8
2½	15	0.6944	1.200	10x10
3	18	1.000	1.000	12x12
3½	21	1.3611	0.857	14x14
4	24	1.7778	0.750	16x16
4½	27	2.2500	0.667	18x18
5	30	2.7778	0.600	20x20
6	36	4.000	0.500	24x24
7	42	5.444	0.429	28x28
8	48	7.1111	0.375	32x32
9	54	9.000	0.333	36x36
10	60	11.111	0.300	40x40
11	66	13.444	0.273	44x44
12	72	16.000	0.250	48x48
13	78	18.778	0.231	52x52
14	84	21.778	0.214	56x56
15	90	25.000	0.200	60x60
16	96	28.444	0.188	64x64
17	102	32.111	0.176	68x68
18	108	36.000	0.167	72x72
19	114	40.111	0.158	76x76
20	120	44.444	0.150	80x80
21	126	49.000	0.143	84x84
22	132	53.778	0.136	88x88
23	138	58.776	0.130	92x92
24	144	64.000	0.125	96x96

Example: Assume it be required to force 32,000 *C.F.M.* through a 48-inch × 48-inch duct in which friction loss, etc. is 1-inch water gauge, using a 72-inch diameter wheel which has an outlet 48 inches x 48 inches. Temperature of air 62° — Air velocity = 32,000 ÷ 16 = 2,000 feet per minute = $33\frac{1}{3}$ feet per second.

$$A.V.P. = \frac{(33\frac{1}{2})^2}{8\frac{1}{2}\,(460 + 62)} = 0.25 \text{ inches.}$$

$D.P. = S.P. + A.V.P. = 1.00 + 0.25 = 1.25$ and
$A.V.P. \div D.P. = 0.25 \div 1.25 = 20$ per cent.

In the table note that the ratio of opening is 60 per cent, and when $D.P. = 1.25$ inches the $C.F.M. = 2{,}000$; $S.P. = 1.00$; $R.P.M. = 665$;

and *B.H.P.* = 0.719. Multiplying these quantities by the factors taken from the table above we get: *C.F.M.* = 2,000 × 16 = 32,000; *B.H.P.* = 0.719 × 16 = 11.5; and *R.P.M.* = 665 × 0.25 = 166 to do the work assumed.

"Sirocco" fans are made double-inlet, double-width wheel, double-width casing, and double-size outlets, which, of course, have twice the capacity and twice the power of single-width fans at the same pressure. The tables above refer to single-width fans.

Should pressures higher than those given in the table be encountered, the quantities can be calculated by the fact that the *C.F.M.* and *R.P.M.* vary directly as the square root of the dynamic pressure; that static pressure varies directly as the dynamic pressure; and the *B.H.P.* varies directly as the product of dynamic pressure and *C.F.M.* For example: Assume 70 per cent ratio of opening, 2.5 inches *D.P.* Find *C.F.M.*, *S.P.*, and *B.H.P.* At 2 inches *D.P.* the *C.F.M.* = 3,030; *S.P.* = 1.426; *R.P.M.* = 819; and *B.H.P.* = 1.643.

Now 2.4 ÷ 2.0 = 1.25, and $\sqrt{1.25} = 1.12$. The new *C.F.M.* = 3,030 × 1.12 = 3,388; the new *S.P.* = 1.426 × 1.25 = 1.782; the new *R.P.M.* = 819 × 1.12 = 916; and the new *B.H.P.* =

$$\frac{1.643 \times 2.5 \times 3380}{2.0 \times 3030} = 2.29.$$

Of course these new quantities are subject to correction according to size of wheel, the same as quantities taken directly from the table.

The table can also be interpolated by the method above given.

HEATING BY FORCED CIRCULATION OF HOT WATER FROM A CENTRAL STATION

Heating from a central plant is most common in localities where the general run of buildings are not of sufficient size to justify the expense of private plants; and even where no exhaust steam is available and all the heating is done directly from the coal, a saving in cost of labor and fuel is effected.

In generating stations where the electrical energy is used in lighting the buildings, the utilization of the exhaust steam from the power units results in a marked degree of economy.

Requisites for successful operation. The power plant would be located as near as possible to the center of gravity of the district served, to avoid excessive loss of heat in the underground transmission lines, and there must be a large connected heating load. A large plant should be located on a railroad siding or by a navigable river to insure economical delivery of coal, and a plentiful supply of good water must be available.

Advantages of hot water over steam, where condensing engines or turbines are used. With condensing engines the water heaters are placed between the engines and condensers, and heat that otherwise would be thrown away in the condenser overflow is utilized, and a saving effected in amount of condenser water.

Less heat is dissipated by radiation from the piping with water at an average temperature of 160° than with steam at 212°, and hot water is best adapted to undulating ground, the mains following the contour of the surface, and branch mains or surface connections being taken off at the highest points to prevent the formation of air pockets.

Economy of operation with hot water is not dependent upon the adjustment of delicate parts, such as thermostats, etc., and the same efficiency is maintained year after year.

Regulation. With all systems of heating the radiating surface is proportioned to obtain the desired room temperature with minimum outside temperature and with all radiation in use. Steam as the heating medium (unless a vacuum system is used) must entirely fill the system at a temperature of 212°, requiring a large amount of heat. The average outside temperature during the usual heating season of 200 days is 35° F., hence on the majority of days only a small amount of heat is required, and hot water will distribute this evenly throughout the entire system. Thermostatic control and vacuum systems give close regulation for steam, but these devices generally require careful adjustment, with frequent inspection to maintain efficiency, while hot water, regulated from the power house, has been found to be very satisfactory without automatic temperature control. The temperature of the circulating water is proportioned to suit varying weather conditions, and the following temperatures of circulating water have been found to be satisfactory:

TABLE I

With open expansion tank	
Outside Temperature	Water Temperature
Degrees F.	*Degrees F.*
50	140
45	140
40	150
35	160
30	165
25	170
20	180
15	185
10	190
5	195
0	200
− 5	205
−10	210
−15	215
−20	215

TABLE II

With closed expansion tank	
Outside Temperature	Water Temperature
Degrees F.	*Degrees F.*
50	150
45	155
40	160
35	165
30	170
25	175
20	180
15	185
10	190
5	195
0	200
− 5	210
−10	220
−15	230
−20	240

Limitations of hot water system. Water at 180° weighs 60.5 pounds per cubic foot and produces a static pressure of $60.5 \div 144 = 0.42$ pound per foot or 42 pounds per square inch per 100 feet of head, and this head should rarely be exceeded due to the excessive pressure on the pumps, piping, and radiators, and the tendency to produce leaks and rupture of joints.

Quality of materials. Selection of materials is determined by considerations of efficiency, durability, and first cost, in the order named. Quality of materials and workmanship especially in the conduit line, should be of the best.

Conduits. Five to 12 per cent of the total heat transmitted is lost by radiation from the distributing mains, and as this creates an operating expense which is continuous year after year it should be made as small as possible. Where funds are available, concrete tunnels not less than 5 feet 0 inch wide by 6 feet 6 inches high should be used to receive the piping, but when funds are limited material for the trenches may be wood, tile, brick, and concrete. The best and most recent commercial types of conduits comprise the use of hollow tile, brick, or concrete walls resting on a concrete base, with hollow tile or reinforced concrete covers, the whole made as waterproof as possible by a 1-inch layer of cement mortar on sides and top. The piping is provided with sectional covering of magnesia, asbestos, or wool-felt, or the entire air space around pipes is packed full of mineral wool, asbestos, or magnesia.

All piping in conduits is supported on pipe rollers.

Service connections vary from 1½ to 2½ inches in diameter and are laid at an average of 3 feet below the surface of the ground. Conduits for service connections should compare favorably with the main conduits in quality of materials, though 4-inch thick wood log pipe covering, lined with tin or asbestos, is generally used and answers every requirement.

The drainage of conduits is secured through lines of 4-inch tile placed at side of foundations, with outfall to sewer or catch basin.

Expansion. The expansion of wrought iron is 0.00008 of an inch per foot per degree rise of temperature, which for a hot-water main under ordinary working conditions would equal .013 inches per foot of length. Experience has shown, however, that an increase in length of 1 inch for each 100 feet will approximate actual results.

Offsets made with 90° pipe bends, right-angle turns or expansion joints spaced from 350 to 500 feet apart, with anchors midway between are used to take up the expansion. Spacing of offsets for district heating in cities is determined by the length of blocks, an offset usually being made in each street crossed by the mains. Straight runs of pipe between anchors are laid and secured in place, and are of such lengths that the last joint to be made up in the offset is open an amount equal to one-half the computed expansion between adjacent anchors. The drawing together of this joint provides a stress in the offset when cold equal to that which will be developed when the pipe becomes hot. The pipes are offset from 25 to 30 times the diameter of pipe, the length of the offset usually being equal to the width of the street crossed, and as all turns are made with long-radius pipe bends no great amount of friction is introduced by their use.

A maximum movement of 5 inches is allowed for expansion joints which determines the maximum spacing; and they should be simple and of the slip-joint type, with cast-iron body, brass sleeve, and a type of metallic packing which may be easily renewed.

Anchors. The spacing of anchors is determined almost entirely by the conditions governing the location of the devices to take up expansion, though in general the mains should be anchored at or near each branch and at important service pipes.

Anchors are of two general types, one integral with the joint at which it is used, such as expansion joints or anchor tees bolted to the floor of the conduit, and the other in the form of pipe bands bolted around the pipe. The latter should be applied on each side of a coupling or other fitting to ensure against slippage, and should extend at least 9 inches into the brick or concrete walls of the conduit. Special piers of brick or concrete are often constructed to provide a secure fastening for anchors.

Valves. Only straight-way gate valves are used, and these are placed on the trunk mains at the central plant and at such points throughout their length as will allow certain portions of the system to be shut off for repairs without cutting out the entire district; on all the branch mains as they leave the trunk; on all by-pass lines; and on all service connections to buildings.

Manholes. Manholes are placed at all valves on mains and at expansion joints, and are constructed of brick or concrete with cast-iron frame and cover. Frames should have not less than 22 inches diameter clear opening, and joint between frame and cover should be practically water-tight.

Radiation in individual buildings. The heat lost by exposure from each building in British thermal units is found by established rules, a temperature 10° above the lowest recorded for the locality being used as a basis, and the result divided by 170 will equal the square feet of direct cast-iron radiation required. Radiators are placed under windows where possible, and in the basement approved types of wall radiators or wrought-iron pipe coils are suspended from the ceiling.

In many systems now in successful operation a water temperature as high as 212° has been used in proportioning the amount of radiating surface required for minimum outside weather conditions, the British thermal units lost from the building being divided by 250 to find the square feet of direct radiation required, since water at 212° will transmit the same amount of heat per square foot as steam at the same temperature. During most of the heating season the outside temperature is considerably higher than the minimum for which the radiation is proportioned, and the water can be circulated at a temperature of 180° or lower. The larger line losses which occur at the higher water temperature are thus limited to a few days only of the heating season, and are more than compensated by the decrease in size and cost of the whole installation. A closed expansion tank is used with this system, and for extreme weather conditions the water may be circulated at temperatures considerably in excess of 212°.

Layout of mains. A drawing showing the location of the power-house and the buildings to be served should be prepared, and the square feet of radiation required or the heat to be supplied in British thermal units should be noted for each building. The mains are then laid out to serve the buildings with the shortest possible runs, conduits being run in alleys and unpaved streets wherever possible, by reason of the lower cost for installation and repairs. Valved by-passes are provided between important points, and the main trunk lines are cut as little as possible.

Two systems of mains are in common use, the 1-pipe circuit and the 2-pipe circuit. One-pipe mains are used generally where a small number of buildings, often at considerable distance apart, are to be heated, the water making a complete circuit through a single main of a uniform diameter, the service pipes to the individual buildings being shunts from the main itself. Individual shunts are the same pipe-size from end to end, radiator connections being taken off at necessary intervals and "Y" fittings provided where each shunt leaves and returns to the main, to induce flow through the building. The supply and return connections of each shunt are kept as far apart in the main as the length of the building will allow, to provide sufficient resistance to cause the water to flow through the shunt, and a valve is sometimes inserted in the main between the connections to control this resistance. Occasionally the main itself is carried through each building, the radiation being supplied by risers from shunt circuits of uniform size taken off within the building, a valve being placed in the main between supply and return connection to shunts to control the flow in same. In individual buildings where the radiation will never be shut off, the entering main is divided into a number of circuits of radiators in series (the combined sectional area of the pipe connection being made 50 per cent greater than that of the main) which re-unite into a single main on leaving the building at the far end. Circulation in low buildings may be forced by arranging all the radiation in one or more series circuits, the return from one coil continuing as the supply to the next, between the supply and return service connections. In high buildings the water is carried upward through a main riser to the distributing main in the attic, thence downward through 1-pipe risers to the return mains in basement and out to main in street, the circulation in individual radiators being caused by gravity only. Radiator connections enter radiator at top and leave same at bottom. "Y" fittings or distributing tees often being used to ensure positive circulation.

Vertical offsets over doors and at all other points where a horizontal main turns downward are provided with air valves of the float type.

A velocity of flow up to 12 feet per second is maintained in the 1-pipe mains since the cooled water from one building becomes in part the supply water for the next; and as the force producing circulation in the service pipes is small, larger sizes are used for these than with the 2-pipe system.

The 2-pipe system is used for large installations and is best adapted to serve contiguous buildings, as in city blocks. Supply and return mains of equal size and in same conduit radiate from the central plant, with suitable reductions in size as the total outlying radiation becomes less. Circulation in the service pipes and mains of individual buildings is caused by the difference in pressure between the supply and return mains.

The size of mains for either system is dependent upon the amount of water to be circulated and the velocity of flow, which, as previously stated, is made 2 to 3 feet higher per second for the 1-pipe than for the 2-pipe system.

Radiator connections. The size of supply and return connections to radiators and pipe coils depends upon the force producing flow through same, and hence upon the layout of piping and connections.

Radiators dependent entirely upon gravity for circulation are tapped according to standard practice for gravity work, the size varying with basement mains and overhead mains, and according to whether a 1-pipe or a 2-pipe system of risers is used.

Where the radiators or coils are arranged in series the size of pipe for the whole circuit is proportioned according to the amount of radiation and the friction loss in the total length of circuit, a 2-inch pipe carrying generally from 500 to 700 square feet of radiation; and the total area of connections, where a 1-pipe main divides into a number of series circuits, is made 50 to 100 per cent greater than the area of the main itself.

Due to the widely varying conditions with different systems found in actual practice, the size connections for all except gravity circulation are largely determined for each individual case by the judgment and experience of the designing engineer.

Water required to be circulated. Water in cooling from 180° to 150° gives up 30 B.t.u. per pound, hence the total heat lost per hour from the group of buildings supplied by each branch, or contemplated by future extensions to the system, plus 10 per cent additional for transmission loss, divided by 30 will give the pounds of water required for the branch. Water at 180° weighs 60.5 pounds per cubic foot, hence the pounds of water required divided by this figure will give cubic feet per hour. The cross-sectional area, and hence commercial size, of any pipe is then found by dividing the total cubic feet per hour by 3,600 × allowable velocity in feet per second, or

$$\frac{\text{pounds water per hour}}{60.5 \times 3600 \times \text{allowable velocity in feet per second}} = \text{Cross sectional area of pipe.}$$

The area of trunk mains is found by dividing the total cubic feet of water per second from branch mains by the allowable velocity of flow. This velocity is ordinarily made from 5 to 10 feet per second, the smaller values being used for branch connections and outlying mains, where they serve to compensate the rapid increase in frictional resistance with decrease in diameter of pipe. Velocities should be limited to 10 feet per second as a maximum, in connection with the largest amount of radiation contemplated by future extensions to the system, due to the rapid increase in friction with increase of speed as shown by Table III, values of which are found by the formula for hot water, $h = \frac{0.32V^{1.86}}{10D^{1.25}}$ where h is the loss in friction in feet per 100 feet of length, D is the diameter of pipe in feet, and V is the velocity in feet per second.

TABLE III

Velocity in feet per second

Pipe size in inches	2	3	4	5	6	7	8	9	10
Inches									
2	1.09	2.32	4.06	6.02	8.46	11.25	14.43	17.96	21.88
3	0.658	1.40	2.45	3.62	5.08	6.76	8.70	10.80	13.20
4	0.459	0.980	1.70	2.52	3.54	4.70	6.04	7.60	9.17
5	0.349	0.742	1.29	1.92	2.70	3.57	4.60	5.70	6.97
6	0.276	0.588	1.03	1.52	2.14	2.83	3.64	4.53	5.53
7	0.228	0.485	0.848	1.25	1.75	2.34	3.00	3.72	4.56
8	0.193	0.411	0.717	1.06	1.50	1.98	2.54	3.17	3.86
9	0.166	0.354	0.617	0.913	1.28	1.70	2.19	2.72	3.33
10	0.146	0.311	0.541	0.800	1.12	1.50	1.93	2.37	2.92
12	0.116	0.246	0.431	0.638	0.900	1.19	1.53	1.91	2.32

The friction head in feed divided by $\frac{144}{60.5}$ or 2.38 becomes the head in pounds per square inch.

Pipe bends instead of fittings are used wherever possible, and where runs of pipe between fittings are short, 10 per cent is added to the friction loss in the pipe to cover the addtional loss in the fittings.

In a well-designed plant with a static head not larger than 45 pounds, average outflow and return gauge pressures of 65 and 20 pounds respectively will be found, and the differential pressure due to friction between the supply and return mains, which the pump must constantly overcome, will vary with the size of installation from 25 to 50 pounds, and on account of the tendency to produce leaks and rupture of joints should never exceed the last-named amount. Pipe sizes should be made large enough to assure this. The static heads on suction and delivery sides are equal, hence the only work required of the pump is to overcome the friction due to the velocity of the moving water in the piping system.

For example, the size supply and return pipe required to carry 20,000 square feet of radiation, transmitting 170 B.t.u. per square foot, at a distance of 100 feet, with a loss in head of 1 foot, and water in radiation cooled 30°, is found to be 6 inches as follows: 20,000 $\times$ 170 + 5 per cent line loss = 3,570,000 B.t.u. per hour. 3,570,000 $\div$ 30 $\times$ 60.5 $\times$ 3,600 = 0.546 cubic foot water per second. Area of 6-inch pipe = 0.196 square foot, hence 0.546 $\div$ 0.196 = 2.8 feet per second and from Table III, by interpolation, the loss of head for 200 feet of 6-inch pipe and velocity of 2.8 feet per second is 1 foot, equal to 0.42 pound, per 200 feet of pipe.

When buildings can be reached by a circuit with the far end returning to the power house, there is less friction loss with the 1-pipe than with the 2-pipe system, hence the former should be used.

In 2-pipe work a tabulation of the loss in head for each section of main will show the circulating pressure between the supply and return mains at any point, and the friction loss in all laterals should be proportioned to the circulating pressure at the point where the lateral begins. A throttling union, consisting of an ordinary union enclosing a hardened steel disc with a round orifice in its center, is often installed on each branch return connection near the controlling valve, the frictional resistance being regulated to the desired amount by varying the size of the opening in the disc. This device is particularly useful to prevent short-circuiting in branch mains which are installed with excessive capacity in contemplation of future extension.

A circulating pressure of at least one pound should be maintained at end of each branch.

Table IV gives average values for the drop in pounds per 100 feet of flow and return main, per 1,000 square feet of radiation with the commercial sizes of pipe up to 10 inches. Average velocities are used, increasing as the pipe size becomes larger, and due consideration is given to the fact that, with a 2-pipe system having branch connections at frequent intervals, from 50 to 70 per cent only of the total volume of water is transmitted the full 100-foot lengths, the friction being correspondingly decreased.

TABLE IV

Radiating surface in square feet	Pipe size in inches										
	2	3	3½	4	5	6	7	8	9	10	12
1,000......	0.50	0.09									
2,000......	1.10	0.25	0.13								
3,000......	2.50	0.40	0.20	0.16							
4,000......	4.00	0.62	0.30	0.24							
5,000......	8.00	0.85	0.43	0.30	0.10						
6,000......		1.20	0.64	0.40	0.13						
7,000......		1.60	0.84	0.50	0.15						
8,000......		2.00	1.04	0.60	0.19	0.10					
9,000......		2.60	1.30	0.75	0.24	0.12					
10,000......			1.60	0.85	0.30	0.15	0.12				
15,000......			3.10	1.70	0.60	0.25	0.20				
20,000......				2.85	1.00	0.40	0.28	0.09			
25,000......				4.30	1.50	0.60	0.38	0.15	0.10		
30,000......					2.20	0.85	0.50	0.22	0.14		
35,000......					3.00	1.20	0.65	0.30	0.19	0.10	
40,000......					4.00	1.50	0.84	0.39	0.25	0.14	
45,000......						2.00	1.05	0.50	0.31	0.18	0.09
50,000......						2.50	1.25	0.62	0.38	0.22	0.15
75,000......						5.50	2.40	1.30	0.82	0.45	0.25
100,000......							4.00	2.25	1.35	0.75	0.40

Because of the widely different conditions for each installation, the proportioning of pipe sizes is determined largely by the judgment and experience of the designing engineer. It is suggested by the writer that a curve be plotted for each pipe size with friction drop in pounds per 100 feet, and square feet of radiation, respectively, as ordinate and abscissa. A few ordinates may be computed for each pipe size from Table III, due allowance being made in 2-pipe work for the decrease in friction resulting from the loss of water at each branch connection between the 100-foot points, and intermediate values being given directly by the curve.

Central plant equipment. The equipment of the central plant for forced hot-water circulation system of heat consists in general of apparatus for reheating and circulating the water, and is the same for either type of system. A plant designed for heating only is provided with steam boilers to supply high-pressure steam to drive the circulating pumps; an exhaust heater in which the exhaust steam is condensed the latent heat being absorbed by the circulating water; and water heating boilers to furnish the additional heat needed. The water is forced from the pump through the heaters, thence through the heating boilers to the flow main in the street.

Where heating is done in conjunction with the generation of electricity, the exhaust steam from all units is used to reheat the water of the heating system. Where sufficient exhaust steam is not available at all times a live-steam heater is installed as a booster, and by which the whole system can be taken care of temporarily.

Many plants have been equipped with economizing coils in the smoke duct between boilers and stack, but because of a rapid decrease in efficiency with length of service, and constant need of repairs, their use has been generally abandoned.

Co-minglers or injectors in which the exhaust steam and circulating water are mixed directly, as in an open-pipe feed-water heater, are used to some extent, and where they do not introduce oil into the heating system have proved very efficient.

The return water is passed through one or more units, carrying live or exhaust steam or flue gases, either in series or parallel. Two or more combinations are provided and serve as a means for regulating the temperature of the water.

Exhaust and live steam heaters. Both types of heaters are cylindrical steel shells with heads bolted on, and with $1\frac{1}{2}$-inch charcoal iron, or 1-inch corrugated copper or brass tubes, expanded into steel plate partitions. Tubes are generally staggered and are placed far enough apart to prevent weakening the tube sheets. Heaters are placed on end to economize floor space, are located close to the circulating pump on the discharge side, and are by-passed so that either one or both may be used as conditions warrant. Steam enters the heaters near the top and surrounds the tubes, through which the water flows upward, the hottest water coming in contact with the hottest steam thus insuring the highest temperature of water possible with a given quantity of steam.

With return water at 150° F., a transmission of 6000 B.t.u. per square foot per hour with steel tubes and 7,000 B.t.u. with copper or brass tubes is allowed, and the size of exhaust heater determined accordingly. The heat transmitted by the live steam heater will vary with the pressure of the steam, and as a water temperature as high as 240° is often desired for abnormal outside weather conditions the live steam heater is designed to withstand the full boiler pressure, the tube surface usually being one-third to one-half that of the exhaust heater. Standard practice in boiler design is followed in determining thickness of shells and spacing of rivets.

Heat available per pound of exhaust steam. The heating value of exhaust steam will average 85 per cent of that of saturated steam at the same pressure or 850 B.t.u. per pound.

Size of heater connections. Exhaust steam at atmospheric pressure occupies a volume of 26 cubic feet per pound, and a velocity of 6,000 feet per minute is allowed in piping, hence

$$\frac{\text{pounds steam per minute} \times 26}{6{,}000} = \text{Area of steam connection to heater in}$$

square feet.

Each pound of water absorbs 30 B.t.u. in becoming heated from 150° to 180°, therefore $850 \div 30 = 28$ pounds of water per pound of exhaust steam.

Circulating pumps. Pumps are usually of the centrifugal type and operate with an average efficiency of 70 per cent against heads up to 125 feet. For small installations, provision for continuous operation in case of break-down or necessity for repairs is made by installing pumps in duplicate, each of a capacity equal to two-thirds the maximum requirement. In large installations pumps capable of circulating 200 cubic feet of water per minute, and rated at 75,000 square feet of radiation each, are installed in parallel, additional pumps being added as the system is extended.

Pumps are direct-connected to steam turbines or electric motors.

Expansion tank. An expansion tank, with a capacity of 2 to 5 per cent of the total volume of water in the system, is installed in the power house or in the highest building on the line. A closed type of expansion tank is used when the water is circulated at temperatures over 212°, a pressure of 3 to 5 pounds above the static head on the system being maintained from the city water-mains through a regulating valve, or by a small electrically-driven air compressor which is arranged to start and stop automatically. A 2-inch safety valve with waste pipe is also provided. Wherever possible the expansion pipe is taken from the return main as near the suction side of the pump as possible.

Water heating boilers. Boiler headers are arranged so one or more boilers of the battery may be used to supply additional heat to the outgoing water, and in many plants the entire heating is done by water boilers with electric motors to drive the circulating pumps.

A boiler horsepower equals 34.5 pounds of steam evaporated from and at $212° = 34.5 \times 970 = 33{,}465$ B.t.u.

$$\frac{33{,}465}{170 + 10 \text{ per cent}} = 180 \text{ square feet radiation per boiler horse power.}$$

$$\frac{33.464}{30} = 1115 \text{ pounds water to be circulated per boiler horse power.}$$

Gauges and thermometers. Pressure gauges are provided on the supply and return to each pump and on the mains where leaving the power house.

Thermometers are placed on the flow and return connections to each heating unit, and on the flow and return mains where same enter the central plant.

GENERAL INSTRUCTIONS

ISSUED TO DRAFTSMEN BY THE CHIEF MECHANICAL AND ELECTRICAL ENGINEER, OFFICE SUPERVISING ARCHITECT

The first step taken in the design of the mechanical equipment of a Federal building consists in acting on the survey which is secured by the office and forwarded to the Chief Mechanical and Electrical Engineer for check. As the proper design of the drainage system, gas and water piping, and electrical service connections to building are dependent on a correct survey, great care must be taken in acting on same, and the following are the principal items to be noted:

Survey must give location of gas and water mains and sizes thereof. If no gas mains are shown, check survey and state in your note to engineer-in-charge "No gas mains shown." If water mains are not shown, return survey with request that size and location of water main be indicated. In event water or gas mains indicated on survey are smaller than 2-inch diameter (unless the gas is distributed at high pressure), return survey and request size and location of nearest large gas or water main. Many gas mains are now installed in which gas is under a pressure of several pounds and in consequence they are reduced greatly in size.

See that location and sizes of sewers are given, and direction of flow and rate of fall. If an elevation is given on sewer without a specific statement as to what point it refers, request that this information be given, unless there is absolutely no question that sewer can drain a cellar 10 feet 0 inch deep.

In event sewer is shown but no elevation is given, request information relative to elevation of *invert*.

If no sewer is available, and a cesspool or septic tank is not to be used, it will be necessary for the Government to build its own sewer, and you should call special attention to the matter in order that the necessary legal steps may be taken to secure right of way, exclusive jurisdiction, etc.

Examine survey for electric light, power, telephone, telegraph and trolley poles, or for underground conduits; if all these points are covered satisfactorily, check survey.

If no poles are indicated on survey and none appear in photographs, check survey.

If the specific uses of the various poles shown are not noted, or if photographs show poles adjacent to site which are not indicated on survey, request further information.

The second step in the preparation of the mechanical equipment drawings and specifications is the forwarding of data sheets to the custodian of the Government site and the action on same upon receipt of data sheets from him.

These data sheets ask for information not covered by survey and proper answers to the questions propounded must be secured.

Survey and data sheets must be compared to see that they agree and that data sheets are complete. If data sheet states that there are gas works in the city, and survey shows no gas main, the custodian of site should be requested to state size and location of gas mains adjacent to site.

When all the foregoing instructions have been attended to, the draftsman will initial the data sheet and file it in the appropriate data book; and he will be held responsible for failure to secure at this time all necessary data.

The next step in the design of the mechanical equipment is the completion of preliminary drawings, which are tracings of the building plans, prepared by the architectural draftsman, showing arrangement of building.

The mechanical draftsman will indicate on tracings: The entire plumbing and drainage system; all chases necessary for any part of mechanical equipment; the size and location of opening for smoke breeching and stack; size and location of all hot air flues and registers, cold air inlets, ventilators, vent ducts, flues and space required for boilers, fan, heaters, air washers, and other machinery that will be required in connection with heating and ventilating system; location of all outlets, cabinets, tablets and switchboard which will be required in connection with lighting; the space required for elevator machine, tank and pumps that may be required in connection with elevators; the space required for vacuum cleaner; and any other machinery that may be required in connection with mechanical equipment. When floor plans are at scale $\frac{1}{8}$ inch to 1 foot 0 inch, the mechanical draftsman will note on the preliminaries that architectural draftsman is not to indicate on his drawings any plumbing fixtures or piping but must indicate thereon all other items mentioned above and note also on drawings the finish of the toilet rooms.

These preliminary tracings are returned to the architectural draftsman whose duty it is to arrange the building to receive the proposed mechanical equipment.

This preliminary work fixes the design of the mechanical equipment with but little chance to change same later, and draftsmen must read carefully the following instructions before the preparation of the preliminaries.

Consideration must be given to part of country in which building will be located; as to whether a district heating service is available; style of building, uses to which various parts are to be put; appropriation available; and any other facts that will affect design of mechanical equipment. Consideration must also be given to the fact that the assignment of a building as indicated on preliminaries is likely to be changed before occupation, involving division of large rooms, conversion of storage spaces (where provided with light) into offices, etc., and the mechanical equipment must be arranged as far as possible to accommodate such changes with a minimum amount of alteration and expense.

In preparation of preliminaries the survey and data sheets must be consulted, and the layout must be made in pencil and approved by the Mechanical Engineer before any work is inked in. The general design of mechanical equipment for large buildings must be discussed with the Chief Mechanical and Electrical Engineer before laying out same.

All vertical pipes in building must be concealed in chases, furring, lookouts, or closets, except when structural conditions prevent, and then pipes may be exposed in locations other than public lobby and court room. In addition to chases for plumbing pipes, indicate on preliminaries chases for heating risers of sufficient number to provide a chase for each riser, and a sufficient number of risers to require but one radiator on a floor to be connected to same riser.

Heating pipes may be run in same chases with downspouts or vent pipes, but must not be run in chases with soil or waste pipes unless absolutely necessary. No chase or piping to be run in vaults.

Indicate also chases for electric conduits, which must never be run in same chases with heating or water pipes. Chases are not generally necessary for conduits where walls are furred, and need never be provided for distribution conduits except at cabinets.

Between basement floor and under side of fireproofing of deepest first floor beam or girder there must be a clear height of not less than 8 feet 6 inches; this is the *minimum* and must be exceeded when possible.

Horizontal pipes may be exposed at ceilings of basement, toilet rooms, lookouts, mailing vestibule, workroom, and back of screen in money-order room provided screen extends to ceiling. In all other rooms pipe must be concealed in furring or floor construction. Toilet-room floors must not be raised above general floor level without special permission of Chief Mechanical and Electrical Engineer.

An Executive Order requires that hot water for cleaning purposes must be provided for *all* buildings.

All buildings must be piped for gas even though there are no local gas works. This is a special departmental requirement.

To ascertain for preliminary calculation the approximate amount of direct radiation required to heat the building, multiply the extreme outside dimensions of building (length by width) by the distance from first floor to ceiling line of first, second, or third floor, as the case may be, to ascertain the cubic contents of heated space; then ascertain the gross wall area of the building, using extreme outside dimensions and the height as determined above; this amount divided by 4 is equal to the glass area and the gross wall area less glass equals amount of net wall area. The total B.t.u. necessary and the total radiation necessary can be determined quickly by multiplying the gross wall area as above obtained by 45 in ordinary climates and 50 in extreme cold climates to get B.t.u., and the result divided by 150 for water and 250 for steam will give the square feet of direct radiation necessary. Check this by dividing cubic contents heated by 100 for square feet if direct steam and by 60 for square feet if direct hot water. Also check by the rule that 1 square foot of direct steam radiation will be required for each square foot of glass in climates varying from $-10°$ to $+10°$ extreme temperature; add 60 per cent to above for hot water.

Ascertain from data sheets if a district steam or hot-water heating company is in operation or is contemplated in the city where building will be located. If such company exists ascertain the size of service pipe recommended by the heating company to supply the radiation required by the building. If steam is used, ascertain whether heating company will permit service pipe to grade towards street main. In such cases the heating apparatus will be designed to be served from the district heating company and the building will also be provided with boiler for breakdown service.

Be sure that there are openings from outside of building to boiler room large enough to permit installation and future removal of boiler. The top of smoke flue or vent shaft must extend not less than 2 feet 6 inches above top of ridge of roof or level of parapet.

When a masonry flue is used for smoke same must be provided with a terra-cotta lining. The largest terra-cotta lining available is 15½ inches x 15½ inches inside, and where a down-draft furnace is required, or where a larger stack is required, the masonry flue cannot be used. In this case return preliminaries to Mechanical Engineer calling attention to necessity for providing a vent shaft. Indicate size of opening for smoke breeching 2 inches larger than round breeching or 2 inches larger each way than rectangular and give distance to center or bottom above floor.

Note size of opening in vent shaft cover for smoke stack, which opening must be 4 inches larger in diameter than the stack.

To ascertain proper size of coal room for an average Federal building, ascertain the cubic contents based on extreme dimensions and height from bottom of basement to top of flat roof or average height of pitched roof, and figure that one pound of coal will be burned per season for each cubic foot of cubic contents and check on the basis of one-fourth pound of coal per square foot of radiation per day and with 200 days in heating season.

Allow coal to be 6 feet 0 inch deep in room and estimate 50 cubic feet of space per ton of coal. Generally figure to store entire season's supply in the small buildings.

Light outlets are located on preliminaries to aid structural engineer to avoid same in designing framing, and also in order to prepare an estimate of cost of conduit and wiring system. Conditions must be carefully studied and light outlets definitely and correctly located. Where for lack of information relative to construction certain light outlets cannot be definitely located, estimate the number of such outlets and include them in the estimate of cost. (For rules for calculating number of outlets see "Conduit and Wiring.")

Estimate the number of tablets that will be required and determine if reasonably central locations can be obtained for same. If locations are difficult to find, or if tablets will be located on brick walls, obtain from architectural draftsman information relative to exact locations for tablets, and indicate on preliminary the chases as hereinbefore stated.

In all buildings three stories or higher containing a court room, provision must be made for an elevator. If appropriation will not warrant the installation of an elevator, a hoistway or stairwell large enough for a hoistway, and a room suitable for an elevator machine must be provided.

A vacuum cleaning-system will not be installed in a building having a total floor area (including basement) of less than 50,000 square feet. When a system is to be installed indicate space required for machinery and chases necessary for risers (see "Vacuum Cleaning").

Any special machinery or appliances such as pumps, tanks, etc., that may be necessary on account of local conditions, must be located on preliminaries in order that space may be reserved for same.

In preparing preliminaries for extensions the report of the draftsman detailed to secure data must be carefully considered (having in mind also the amount of the appropriation available) in determining whether the entire mechanical equipment of the old building must be abandoned, or whether same shall be extended, to serve the addition.

Consult Chief Mechanical and Electrical Engineer in regard to all extensions, but before taking up the subject be in possession of all data, including amount of appropriation available per cubic foot of extension.

The estimated value of the plumbing and drainage, plumbing marble, heating and ventilating apparatus, gas piping, conduit and wiring, clock system, telephone system, vault protection system, elevators, lighting fixtures, etc., must be carefully determined, and noted on the preliminary drawings. The conduit and wiring system estimate placed on preliminaries is to include all special conduit systems.

To ascertain the cost of the plumbing and drainage where the building is within 100 feet of city sewer to which it will connect, add together the number of water-closets, urinals, slop sinks, lavatories, shower bath, sinks, fire hose racks, and take four wall hydrants as one fixture and hot water boiler and heater as one fixture. Multiply the number of fixtures so ascertained by $125.00 for 80 fixtures and less, and by $115.00 for more than 80 fixtures.

To ascertain cost of plumbing marble multiply the number of fixtures in toilet rooms by $75.00. If a terra-cotta private sewer must be run, estimate it at $1.00 per lineal foot if in earth and $3.50 if in rock; and if brick or granite pavement must be replaced add $1.00 per lineal foot to above. Estimate $75.00 for each manhole; $200.00 for a cesspool, and $300.00 for a septic tank. For each water filter of 50 gallons capacity per minute (in new buildings) allow $600.00. Cost of gas piping system $3.50 per outlet.

To estimate the cost of heating apparatus where direct radiation and a portable steel boiler with plain grate is used, multiply the number of square feet of radiation by $1.25 for steam and $1.10 for hot water if building is located in northern or eastern part of United States; and by $1.50 for steam and $1.35 for hot water if building is located in south or southwest. To this add $600.00 if downdraft furnace is used. Brick-set, horizontal, return tubular boilers would not materially change the estimate.

Add for cooling coil and connections for outside heating system 50 cents per square foot of indirect radiating surface.

For automatic-temperature control add 60 cents per square foot of radiation. A fan system with air heated to 70° for ventilation only and with an air washer, will cost approximately $300 per 1,000 cubic feet of air per minute for steam, plus 60 per cent for hot water for ventilating system only, exclusive of registers.

Gravity-steam-indirect will cost $2.00 per square foot of radiation.

Vacuum systems will cost approximately 50 cents per square foot of radiation in addition to cost of a standard one-pipe gravity-return apparatus.

To estimate the cost of conduit and wiring system multiply the total number of ceiling outlets, bracket outlets, plug receptacles and post-office workroon floor outlets by $14.00 where building is located near a large city; by $16.00 when somewhat remote from a large city; and by $20.00 when in far west or south. For a check rule to ascertain the number of gas or electric outlets in a building, divide the total cubic contents by 2,000. This result is outlets, not lights, as the number of lights will average 5 to the outlet.

The cost of the lighting fixtures will be approximately $15.00 each and their aggregate cost, including installation, will be the same as that of the conduit and wiring system.

Cost of conduit and wiring for the lighting system of an old fireproof building is $25.00 per outlet; wood construction $20.00 per outlet.

Vault protection systems estimate at $20.00 per vault.

Telephone systems $10.00 per outlet, for conduit and boxes; no wire or instruments.

Clock system at $10.00 per outlet for conduit and boxes alone.

Watchman's clock systems at $10.00 per outlet for conduit and boxes alone.

Cost of clock system complete $35.00 for each secondary clock.

Estimate for vacuum cleaning system:

Six-sweeper plant	$3,500
Four-sweeper plant	3,000
Three-sweeper plant	2.500
Two-sweeper plant	2,000

Each hydraulic lift operated by city water-pressure direct, estimate at $2,000.00. This will include street connection.

Hydraulic lift with pumping plant estimate at $3,000.00. Push-button dumb-waiters (office standard) will cost $2,000.00. Push button-freight elevator not exceeding 1200 pounds capacity, $3,000.00.

For each standard drum-type electric passenger and freight elevator estimate $6,000,00. For geared traction type the cost for each elevator will be about $7,500.00.

Very small hand-power lifts for machinery only, $150.00.

Where shaft and enclosure are to be built for hand-power lift with car above 4 feet x 4 feet and capacity of 300 pounds, cost will average $600.00.

Based on the architectural cubic contents of a building, which is obtained by multiplying the extreme outside dimensions of building by the distance from basement floor to top of balustrade on a flat roof building or to mean height of roof on a steep pitched roof, the cost of the mechanical equipment will approximate the following figures when intelligent estimates are secured from contractors:

	Per cubic foot
Plumbing and plumbing marble	$0.02
Direct heating	.0125
Conduit and wiring	0055

The approximate cost of mechanical equipment based on total cost of our standard building is about:

	Per cent of total cost of building.
Plumbing and plumbing marble	6
Direct heating	3½
Conduits and wiring	1½
Gas piping	0.4

Approximate cost of mechanical equipment of a small one-story post-office building is roughly 12 per cent, and for a large building from 15 per cent to 20 per cent, of total cost of building (exclusive of land).

The cost of our small standard buildings for entire completion including mechanical equipment is 35 cents per cubic foot. When the proposed building figures out below this, consult Chief Mechanical and Electrical Engineer.

The cost of our standard extensions where some changes of magnitude occur in old part of building will average 45 to 50 cents per cubic foot of the *extension* only When the figures are below this, consult Chief Mechanical and Electrical Engineer.

Attention is called to the fact that proposals based on architectural or mechanical drawings made on a scale of ⅛ inch to the foot, will average 10 per cent higher than proposals based on same work on ¼-inch scale to the foot.

The cost of the mechanical equipment of our standard one-story post-office buildings will average about as follows:

Plumbing	$2,500
Plumbing marble	900
Heating apparatus	2,500
Conduit and wiring	900
Gas piping	300

For our standard three-story building it will average:

Plumbing	$4,000
Plumbing marble	1,300
Heating apparatus	4,100
Conduit and wiring	2,300
Gas piping	400

Upon completion of preliminaries, prepare the insert specification for mechanical equipment if the mechanical equipment is to be let with the building, as is the case except in larger buildings where the cost of the entire mechanical equipment will approximate $25,000.

The mechanical draftsman must follow up the job and at the proper time obtain of the architectural draftsman floor plans, and trace for finished heating and lighting if said floor plans are made $\frac{1}{4}$ inch to the 1-foot 0 inch scale; and for plumbing, heating and conduit and wiring if said floor plans are made $\frac{1}{8}$ inch to the 1-foot 0 inch scale.

When an extension is to be made to an old building an engineering draftsman is detailed to visit the building for the purpose of obtaining all data necessary as a basis for preparation of drawings and specifications for mechanical equipment of the extension and for any required modifications, etc., in the apparatus in old portion of the building.

A draftsman detailed for such duty must, before leaving the office, provide himself with all necessary drawings of the old building, a set of drawings of the proposed extension, a B. and S. wire gauge, and a set of data sheets: familiarize himself with the proper use of transportation requests, with the keeping of an expense account, the preparation of vouchers, etc.; and ascertain the amount appropriated for the extension, and the estimated cost of structural work of extension, and changes in old building.

He must not discuss with the officials at the building the assignment, etc., of the proposed extension, nor permit anyone to examine the drawings for same; and must obtain and note data in accordance with the following general instructions:

Conduit and wiring system. Indicate location of all light outlets, noting whether same are gas or electric or both, and ascertain the number of lights. Note the type of fixture, its condition, whether wired, and if provided with finial or pendant switch. If new lighting fixtures are necessary obtain all data necessary in order that specification for same may be prepared.

Indicate swing of all doors of building.

If electricity is used in old building for lighting, indicate location of snap switches, size of same, height above floor, and lights controlled by each switch. Give location of switch tablets or switchboards. Make diagram of same showing number, type, and size of switches and fuses. Also indicate whether slate or marble is used for panels and ascertain condition of same. Note especially if any spare switches are on panel boards and ascertain their size; also note location of wiring compartment on tablets and note construction of cabinets. If capacity of switch is not marked on same obtain dimensions of blades.

Note manner in which wires are run, whether in conduit (iron or paper), in moulding, or on knobs or cleats, and condition of same. If possible, indicate runs of all circuits and groups of lights controlled by each switch on tablets.

If possible give size of all circuits and in every case give size of main and subfeeders. Note whether feeders are two or three-wire. Where feeders are stranded measure outside diameter of copper cable and if possible give size of wire in strands and number of strands in outside layer.

Note floor construction, fire-proof, wood or otherwise, and whether finished floors are wood, tile, or whatever construction. Give direction of run of floor boards in finished floors.

Have superintendent or manager of lighting company fill in service data sheet, answering fully questions No. 15 and No. 17. Get answers to above questions also from telephone company.

Make a sketch showing exact location on or distance from site of all poles (electric light and power, telephone and telegraph). Indicate present services entering building and state whether overhead or underground, and give size.

Heating and ventilation. Indicate on the drawings the location, size, construction and condition of all direct and indirect radiators in old building, and size of connections, risers, and branches thereto. State whether radiator connections are above floor, in floor construction, or at ceiling below. Indicate location, size, and elevation above basement floor of all heating mains, and state type and the name of manufacturer of air valves and radiator valves in place. Indicate on drawings location, size, numbers, construction and condition of boiler or boilers; give grate area, water line, kind of coal burned, size and location of breeching and stack, and state whether or not the draft is good. State if building is satisfactorily heated and ventilated. If there is a ventilating system, show location and size of fans, motors, ducts, flues, registers, etc., and state condition; give elevation above basement floor of all parts of apparatus located near ceiling, and state if system is satisfactory or not. If there are no ventilators, report whether same are needed, especially in assembly rooms. State condition of atmosphere of the city, especially in regard to dust and soot.

Plumbing and gas piping. Indicate on drawings the location of all plumbing fixtures and note type, name of manufacturer, and trade name (if obtainable); also their condition and whether they are satisfactory in number and operation. Give finish of all toilet rooms. Locate all down-spouts and all soil, waste, vent, and water risers of sanitary system.

Indicate location and give size of all horizontal soil, waste, vent, water and gas piping. Give elevation above basement floor of all overhead piping.

Indicate connection of building to city sewer and give size of connection and size of city sewer. Report whether drainage is satisfactory or if water backs up during rains.

Give the distance from basement floor to center of horizontal soil pipes at summit, at point where same leave building, and at not less than two other points. Engage assistance (through custodian) to secure this data if necessary.

Ascertain the condition of city water, to determine if filters are necessary, and the pressure carried.

Fill out and return data sheets, with full report.

Size of Drawings. All tracings must be 21½ inches x 37 inches, with ¾-inch margin; titles in capital letters designating branch of work, i.e., "Heating," "Electric Wiring," etc.

Floor title to be placed midway between side borders, immediately below plan; scale in $\frac{3}{16}$-inch letters immediately below floor title.

Title designating work to be placed midway between floor title and right-hand border line, about 2 inches above bottom border line.

"Chief Mechanical and Electrical Engineer" in two lines to be in small italics, immediately above bottom border line, 6 inches from left hand border.

Building title in right-hand bottom corner, and Supervising Architect's title in left-hand bottom corner, to be placed only on separate contract drawings. Space to be left for same otherwise.

SUGGESTIONS TO SUPERINTENDENTS

The following suggestions to Superintendents of Construction belonging to the office of the Supervising Architect, in relation to the mechanical equipment of Federal buildings, were incorporated in a paper presented at the annual meeting of the Treasury Construction Society in July, 1911. at St. Louis, Mo., and are included herein as being connected with the subject-matter of this book.

The first precaution of the superintendent should be to familiarize himself with the specification (not neglecting the general conditions) and the drawings governing the mechanical equipment, and to make marginal notes relative to any items which are not clear to him, or which appear to him to be in error, or, more important still, where there is a conflict between the drawings and the specification. If such matters are taken up with the office at that time for adjustment, for interpretation, or for whatever action is necessary, it will save a lot of trouble in the future.

If a superintendent has had comparatively little experience with mechanical equipment it is a good idea for him to confer with the foreman on the various branches of mechanical work as soon as they report at the building, frankly state that he is a little weak on those portions of the work, and warn them that while he may not see all the defects during the progress of the work the inspector of mechanical and electrical engineering will be very likely to when he comes along, and therefore that their own best interests will be served by strictly following the drawings and specifications and using no material except that which has been specified and approved.

Cases are bound to arise where structural conditions will prevent the installation of work or materials strictly in accordance with contract requirements, but it should be impressed upon the contractors' representatives at the building that they must not make any change, however slight, without the concurrence of the superintendent. The latter's authority permits him to direct a contractor to change the location of a pipe, a conduit, a cabinet and tablet, etc., where structural difficulties arise, *provided no change in price is involved*, but the order to make the change must be made in writing, so that there may be no misunderstanding, and a duplicate of the letter should be placed on the superintendent's files for his own protection and for the information of the inspector who examines the installation. If the superintendent has any doubt as to his jurisdiction in the matter, or as to the best course to follow, it is well to refer the case to the office in advance of taking any action.

Great care is taken by the office in selecting the materials and appliances to be used in the mechanical equipment, and the letter of approval gives name of manufacturer, trade name, and, where possible, catalogue number. After the formal approval, these materials and appliances are as much a part of the contract as anything that went before, and cannot be changed without permission of the Secretary of the Treasury, or an Assistant Secretary acting for him. And as all these changes cost the Department time and money they should be avoided whenever possible. If a superintendent recognizes the necessity of permitting a change to be made, i.e., where structural reasons demand it, where serious delay would result by insisting upon the use of exactly what has been approved, etc., etc., he should immediately obtain from the contractor a proposal to make the substitution, either with or without change in contract price, whichever the conditions warrant, and should forward it with a brief explanation and with his recommendation. If the conditions which make the change necessary or advisable were not anticipated (as may often be the case where extensions to old buildings are in progress), and an exigency exists, threatening delay to other work, or indicating the possibility of some complication, the superintendent should wire the office, stating briefly the conditions and that a proposal from the contractor has been or will be obtained and forwarded; and this wire should give the amount of money involved, exactly or approximately, if any change in price is contemplated, and state clearly just what material is to be changed and what they desire to use in place of it.

Except under the above conditions the superintendent should see that the contractor uses what is specified and approved, and nothing else, and even though he is not very familiar with steam heating, plumbing, etc., he should not have much difficulty in identifying the approved devices and fixtures with the aid of the usual illustrations and descriptions. The contractors should be discouraged from asking for changes on the ground that they can get "something just as good" for less money, or that their sub-contractors have a large stock of some make on hand and prefer to use it, as these considerations have no weight with the Department, and the requests and refusals cumber the files unnecessarily and get in the way of more important business.

Another very important precaution for the superintendent is to examine the mechanical equipment material as delivered, or as soon thereafter as other duties will permit, with a view to rejecting immediately any that is not in accordance with contract requirements. I have known cases where the office used several thousand words, and an enormous amount of time and patience, in obtaining the removal of inferior material, not acceptable even on the basis of a considerable deduction, which the contractor claimed had been put in with the concurrence of the superintendent, or, at least, without any objection from him, which was construed as being equivalent to permission to go ahead. These troubles, or many of them, would be avoided by a careful examination of material before installation. It is a fact that much of the trouble in making final settlements, so far as mechanical equipment is concerned, comes from unauthorized changes in appliances and materials, all of which have to be adjusted at that time.

The new standard plumbing specifications adopted by the Treasury, War, and Navy Departments, are profusely illustrated and will tend to do away with all uncertainty in regard to the recognition of approved fixtures, etc., so far as new work is concerned.

In connection with heating work superintendents will do well to provide themselves with the Crane Company's hand-book of their various steam specialties, and with the Ideal Fitter's hand-book, published by the American Radiator Company, Chicago, Ill.

While the above-named firms generally decline to send their valuable catalogues to persons not engaged in the line of business to which they cater, they would undoubtedly be supplied to superintendents who wrote in their official capacity and stated that the books were for official use.

Where omissions, additions, or changes are necessary in connection with work already under contract, and the superintendent is unable to get what he considers a reasonable figure, he should forward to the office without delay the best proposal he is able to obtain from the contractor, accompanied by a statement as to the necessity and the value (itemized) of the work, and a recommendation relative to the amount which should be fixed by the Department as compensation. It is not the intention to require contractors to perform additional work without a reasonable profit, and therefore superintendents should be liberal in estimating on same, giving due weight to the possibility of delaying other work under contract, to the distance from the market where the material must be obtained, and to the cost of expressage, freight, etc., adding a margin of not less than 25 per cent for profit, which includes the cost of doing business. With these features taken into account, and itemized in the superintendent's statement, the office will be very apt to follow his recommendations.

In those cases where contractors are ordered to perform work at a fixed price, the superintendent should give it his particular attention, keep an accurate record of the labor and material used, and on completion report the facts to the office so that same may be available either to justify the position of the Department in case of controversy or to rectify any unintentional injustice done the contractor in fixing the price.

Where it becomes necessary for the Department to order any portion of the work done at the contractor's expense, it is even more important for the superintendent to keep careful watch of the work as it progresses, to check up the materials and labor used, and to make sure that the contract requirements are strictly followed in every particular, as any failure in this direction would materially weaken the position of the Department in case of a controversy with the contractor in regard to the basis of settlement.

If a superintendent after due effort is unable to obtain from a contractor a reasonable proposal for work which is necessary, but is *not closely associated* with work under the contract, as, for instance, work in the old part of a building to which an extension is being added, or work in a new building which was not contemplated by the original contract and in no way affects it, as an independent gas or steam service connection, etc., the superintendent should forward such proposal as he is able to obtain from the contractor, accompanying same with an itemized statement of the necessity and value of the work, and with a proposal from some local contractor, or from sub-contractors on the job.

In making estimates for partial payments on mechanical equipment the best results will be obtained by calling on the contractor for a detailed schedule of the values he assigns to the various portions of the work satisfactorily in place (no allowance being due for material delivered and not installed), and using these as a basis of comparison with the estimates made by the superintendent himself, who will thus be in a position to check up any errors in over-estimating or under-estimating on either side before the vouchers are prepared.

The following data may be of service in this connection:

On the heating work the boiler represents *approximately* 30 per cent of the cost of the job; radiation 20 per cent; piping 25 per cent; labor and profit 25 per cent; and when the boiler is set and all piping run, but radiation not connected, the job is "roughed in," and 50 per cent completed.

The plumbing is considered 50 per cent completed, or "roughed in," when all pipes are in place and tested, but fixtures not set. The fixtures represent about 20 per cent of the value of the work, and the cost of installation will average about $10.00 per fixture.

The conduit and wiring system is 50 per cent completed, or "roughed in," when all conduits, steel cabinets, and outlet boxes are in place, but the marble tablets, wiring, etc., have not been installed. The marble tablets cost about 20 per cent of the job, and are worth about $1.00 per circuit to connect. In new buildings conduits of all sizes, in place, will average about $150.00 per 1,000 feet.

When a contract includes the removal of old material no credit should be given this factor under the head of percentages of completion on the semi-monthly reports, as this causes confusion in the office and has sometimes resulted in sending an inspector to the building for a "preliminary inspection" before there was anything for him to see.

Particular attention should be given by the superintendent to the prescribed tests of the mechanical equipment, which he should require the contractors to make in his presence at the proper time. The specifications give full information relative to the kind of certificates required from contractor and superintendent, and it will help the mechanical inspector a good deal if the superintendent will place a copy of such certificates on the building files.

If any portions of the heating apparatus (such as risers in chases) are to be covered in by terra-cotta, etc., the superintendent should have such pipes tested in his presence with steam or water (water pressure not less than 50 pounds), and permit them to be covered if the results are satisfactory. No other portions of the heating installation are to have the non-conducting coverings applied until after the system has been inspected and tested by a mechanical inspector after completion, but the coverings should be at the building for his examination at the time of final inspection, and to insure this result the superintendent should promptly compare the delivered material with the approved samples of covering sent to him from the office, and require the contractors to correct any mistakes immediately.

As indicated by the specifications, when lighting fixtures are under a separate contract, the connection of the lighting fixtures to the wiring system of the building should be deferred until after the latter has been tested out by an inspector of mechanical and electrical engineering, this having been found to be necessary on account of the controversies which used to arise between the wiring contractor and the fixture contractor when defects in the work developed and the responsibility lay between them.

In order to be in a position to fix the responsibility for any defects which may develop during the fixture installation, the superintendent should be present when the fixture contractor makes the prescribed test of gas piping before beginning his work; and it is very important that the superintendent make sure that all gas nipples for lighting fixtures comply strictly with specification requirements, thus avoiding delays on this account after the installation is begun.

Particular attention should be paid to tests of piping, wiring, etc., specified to remain in place in buildings which are being extended, and if any parts are found to be not tight, or in any way unfit for use, a proposal for repairs or renewal, as the case demands, should be promptly forwarded by the superintendent, with his explanation and recommendation.

Where the specification for extension of a building includes the removal of old mechanical equipment the superintendent should carefully note whether the contractor has the privilege of using any of the old material. Such material as the contractor has no right to use should be listed by the superintendent, divided into groups, such as steel and iron, copper, brass and lead, etc., giving the approximate weights, and proposals for purchase and removal should then be obtained and forvarded. The old-metal markets vary greatly, but the following prices are an ndication of what the superintendent may expect under ordinary conditions:

Wrought iron pipe	$8 00 per ton
Old boilers (whole),	4 00 per ton
Iron castings and machinery	10 00 per ton
Copper wire, etc.	0.10 per pound
Light brass castings	0.05 per pound
Lead pipe	0.03 per pound
Old hose	0.02 per pound
Old plumbing fixtures	No settled market price; variable, and generally very low

In regard to old material which is properly considered as débris, the superin-endent should take whatever course will dispose of it with the least trouble and get it out of the way of building operations.

It is the intention of the office to make at least two inspections of mechanical quipment before the final inspection, and to make the first of these when the various branches are from 20 to 50 per cent completed, the exact time being regulated y the exigencies of the service, as there are many places to visit and but few nspectors to do the work. It is particularly important that the superintendents give their best attention to work that is to be covered before the inspector's arrival, nd allow no piping, etc., to be concealed until satisfactory tests have been nade under the prescribed conditions. If a superintendent is in doubt as to vhether certain work should be considered acceptable a call for an inspector will eceive due consideration even before the usual time for making a preliminary xamination.

Probably all the superintendents know that the office requires formal notice rom the contractor, by letter or telegram, when the mechanical equipment is eady for final inspection and test, this precaution being necessary in the event he inspection is delayed or repeated through some fault of the contractor, in which ase the next visit of the inspector is at the contractor's expense. This notice hould come through the superintendent when possible, with his confirmation of he contractor's statements relative to the stage of completion reached, or with uch comments to the contrary as the conditions require. It will be helpful to hose in charge of routing up the mechanical inspectors if the contractor's notice s obtained and forwarded a little in advance of actual completion, provided the onditions are such as to warrant contractor and superintendent in agreeing upon a definite date when everything will be ready for the inspector's examination. When the contractor is unwilling to bind himself to a definite date in advance of actual completion, it will be helpful if the superintendent will confer with the contractor and then give the office his best judgment relative to the probable date of readiness for the inspector. This will not involve the contractor, but will give the office a chance to route this job up with others in the vicinity if an inspector is going that way in the near future. The contractor's notice must follow at the proper time, of course, and a telegram from the superintendent stating that such notice is in his possession will be appreciated, and will frequently save an inspector a long trip back over a recently-traveled route.

Some of the superintendents seem to misunderstand the status or the motives of the inspectors of mechanical and electrical engineering, and a word on that subject may not be amiss.

The inspectors are the direct representatives of the Supervising Architect, selected and appointed because their technical education, their experience, and their judgment are needed in obtaining the execution of the mechanical and electrical branches in strict accordance with contract requirements. In reporting every variation, however minor it may appear to be, they are simply carrying out their orders, and superintendents are not justified in believing that inspectors do this for the purpose of placing them before the Department in an unfavorable light. Judging from my own experience, the inspectors would be very glad if they did not find anything to criticise, and the office would certainly be overjoyed; and yet in cases where numerous and serious defects and omissions have been reported the superintendent in charge of the work has written the office in a strain indicating a spirit of hostility to the inspector, criticising him directly and the office indirectly, and seeming to attribute the blame to everybody but the people at fault, i.e., the contractors and the superintendent. Inspectors differ, just like superintendents and other people, but the average inspector if met in a fair spirit will be very glad to help the superintendent on the branches of work which are his special province, and to give him the benefit of his experience on such points as valuing work in place, estimating percentages of completion, interpreting drawings and specifications, etc.; and will consider these courtesies well repaid if the superintendent on his part will have all papers relating to mechanical equipment, beginning with the acceptance of proposal, carefully filed in proper sequence and readily available for examination, for with this data, including the duplicates of test reports and copies of any orders the superintendent has given for changes due to structural conditions, etc., as previously referred to, the inspector will be saved much time and trouble and the office will reap a corresponding benefit in handling his report.

About two years ago, for good reasons, the office discontinued the old practice of sending a copy of the mechanical inspector's report to the superintendent with instructions to make necessary demands on the contractors, and inaugurated the custom of making the demands directly on the contractors. Good results have been obtained, and the superintendents have doubtless been glad to be relieved of the clerical work involved in the former method. They should, however, follow the contractors up and hasten the completion of the work along the lines indicated by the demand letter, reporting to the office within a reasonable time if the action taken is not satisfactory. If any variations reported by the inspector are acceptable to the Department, either on a deduction basis or otherwise, the superintendent is notified so that he may govern himself accordingly, and the fact that certain items have been objected to by the inspector need not be taken into account by the superintendent (except when there is an obvious error of omission on the part of the office) unless the demand letter sustains the inspector's views.

If a contractor fails to prosecute the mechanical work in harmony with the remainder of the building, or fails to supply omissions and correct defects in accordance with instructions of the superintendent or the office, as the case may be, the superintendent should after a reasonable time address a formal demand to the contractors, sending a copy of same to the office, with a brief explanation (unless the copy is self-explanatory) of the conditions which demand the action. If this does not promptly bring about the desired result it is no use for the superintendent to delay further, and he should report the case to the office for appropriate action.

In the event a superintendent is transferred to another point of duty prior to the correction of defects reported at the time of final inspection of mechanical equipment, he should explain all items carefully to the custodian, and impress on him the necessity of submitting a detailed report as soon as conditions will warrant. Prompt action on this feature of the work will tend to expedite final settlement more than any other one thing, and help the office to avoid many of the criticisms now made on account of slow payments.

Even where the structure and the mechanical equipment are included in one contract the office is frequently called upon to answer questions relative to the use of the heating apparatus during the erection of the building. In these cases the building contractor may use the heating apparatus of the building, or any other medium which he desires, provided he furnishes temporary heat upon demand of the superintendent which is *satisfactory* to that officer.

Where the heating apparatus is under a separate contract the matter of using it for temporary heat is for adjustment between the contractor and the building contractor, and the office is not interested in the basis of adjustment. If the heating contractor does not want the apparatus used, that is his privilege, and the building contractor must find some other means.

In either of the above cases the superintendent should advise the contractor that the office will interpose no objection to the use of the heating apparatus for the purpose of furnishing temporary heat, provided it is presented for final inspection in a first-class condition, in full accordance with contract requirements.

It sometimes occurs that a building is ready for general occupancy before the heating apparatus is entirely completed, although the system is in such condition that it can be placed in service and operated by the custodian's force; and in such cases (as the interests of the Department will be served by the action) the superintendent should request the detail of an inspector of mechanical and electrical engineering, who will note all omissions and defects then existing, after which the system may be operated by the custodian's force on the understanding that the contractor will not be held responsible for any damage due to such operation but must correct all defects reported by the inspector and meet all responsibilities entailed by the "Guarantee" and "Notice to Surety" clauses of the specification.

Where extensions are made to old buildings which are not vacated during building operations, special care is taken in preparing the specifications for mechanical equipment and certain portions of the general conditions under the construction specification, so that the building contractor is bound to insure proper heating of the occupied parts of the building and adequate lighting and toilet facilities, failing which the superintendent has the right to act at contractor's expense. When the superintendent's course in the matter is clearly set forth in the specification, which is the endeavor in all such cases, he should act promptly and discreetly and submit vouchers to the office for the necessary expense, with a letter of explanation. Before proceeding with any "exigency" work under these conditions, it is well for the superintendent to get at least two written proposals from local parties, and accept the one which is best for the interests of the Department, all things considered, forwarding both proposals to the office with the vouchers.

Where the specifications are not clear in regard to the action to be taken by the superintendent in such cases, he should simply obtain and forward the bids with his explanation and recommendation and await instructions.

It may be well to call attention to the fact that some cities require the "owner" to sign the application for a permit to open streets, connect to sewers, etc., and in those instances there is no objection to the superintendent signing the application as a matter of form, provided he accompanies same with a statement that the signing in no way binds the Government or its agents to any payments therefor, as the specifications require the contractor to pay all necessary fees.

At a convenient time it is also well to advise the city authorities that the local regulations in regard to plumbing, drainage, etc., do not apply within the Federal lot line, and therefore that the local inspectors have no jurisdiction.

While the specifications provide that gas and water pipe used in the work outside of the lot line are to be in accordance with the rules of the local companies so far as materials and method of laying are concerned, this does *not* apply to the building sewer; and the specifications do not permit any reduction in the size of the gas and water pipes.

In all the matters treated of in this paper the office must rely to a great extent on the discretion, tact, and judgment of the superintendent, and perhaps it will help him in his work if he will remember that while he may be having a struggle with one building the office is having a struggle with a couple of hundred in various stages of completion. The amount of correspondence from all of them is enormous, and steadily increasing, and anything a superintendent does in the way of avoiding unnecessary additions to it is appreciated. He should not draw the office into a matter that is properly within his own jurisdiction, but if he must write on a subject, should make his communications as brief and explicit as possible. The ideal superintendent is the one who can erect a building in strict accordance with contract requirements, and with the minimum amount of controversy and correspondence, so that if it were not for his semi-monthly reports of progress the office could almost forget that such a building was under way.

INDEX

HEATING AND VENTILATION

Page
Air distribution system 27
Air removal system 39
Air washers 32
Boilers, furnaces, stacks, grates, fuels 16
Boilers, types and sizes 16
Calculating radiating surfaces 6
Coefficients for walls, glass, roof and ceiling surfaces 7
Coefficients for frame building walls 8
Estimating data 41
Estimating detail 42
Fans, kind, size, capacity, power, and speed 20
Fans, steel plate, siroco, cone 21
Fans, system 19
Fans, testing 34
General practice 1
Heaters, used with fans 23
Piping, size of mains, branches and tappings 13
Piping, steam and return, fan heaters 27
Prime movers, motors and engines 27
Radiation direct 10
Radiation direct indirect 11
Radiation gravity indirect 12
Radiation indirect fan system 23
Systems, Dunham 38
Systems, fan 19
Systems, heating 1
Systems, vacuum 35
Vacuum system 35

PLUMBING, DRAINAGE AND WATER SUPPLY

Agricultural drain 50
Air tests 66
Cesspools 48
Cost of tests and certificates 66
Design of system 51
Drinking fountain 64
Estimate data for plumbing and drainage 67
Estimate data itemized 67
General practice 46
General description of fixtures 54
Manholes, sewer 47
Proportioning number of fixtures 55
Refrigeration 64
Septic tanks 48
Sewers 47
Sewers, manholes 47
Sewers, grade 48
Sewers, sizes 49
Size, fixture connections 49
Size, toilet rooms 55
Tests, cost and certificates 66
Tests, plumbing and drainage systems 65
Tests, smoke 66
Tests, water supply systems 66
Uniform plumbing specification 53
Water supply system 56
Water supply system test 66
Water tests 66

GAS PIPING

Branches 73
Bracket outlets 74
Controlling cocks 73
Fixture outlets 74
General practice 72
Hangers 73

Page

Main gas pipe 72
Size of pipes 73
Specification 72
Test of piping 75

CONDUIT AND WIRING SYSTEM

Call bell conduit 98
Conduits, signal system 100
Conduits, size for conductors 78
Conduits, system for time clocks 91
Estimating cost of time clock system 95
Estimating data 89
Estimating in detail 89
Fire alarm system 96
General illumination 82
General practice 76
Load factors 84
Outlets 79
Power factors, light and power 88
Switchboards 88
Telephone conduit 98
Tower clocks 93
Vault protection system 97
Voltage drop 84
Watchman's time detector system 96
Weather Bureau special conduit 99
Wire and cable data 88
Wiring 83
Wiring formulae and tables 85

LIGHTING FIXTURES

Basic data, design and installation 101
Casings 108
Castings 108
Combination 105
Cord drops 110
Design 101
Electric only 105
Estimating 104
Finish 104, 111
Gas burners 111
Gas only 105
Gas piping 108
General practice 101
Glassware 111
Globes 104
Globe holders 109
Inspection and test 113
Installation 101, 113
Insulating joints 110
Lamps and mantels 112
Metals 108
Reflectors 112
Reflectors and globe holders 109
Sockets 110
Switches 110
Type 106
Typical schedule 107
Wiring 109

ELEVATORS

Annunciators 137
Bedplate 132
Brake 133
Buffer 136
Cables and counterweight 125, 137
Capacity and speed 131
Car 136
Car switch stop 135
Connections 137
Controller 134
Drum 132
Emergency switch 135
Finish machine 134
Foundations 132
Gear 132
General practice 114
Guides 131
Guide grips 135
Hoistway 131
Instructions relative to inspection and test 138
Lighting fixture 137
Load 118
Metal grating 131

Page
Motors 132
Overhead supports 131
Pit 131
Pumps 126
Safety devices 135
Sheaves 136
Shop test motors 133
Size of cars 116
Slack cable switch 135
Space requirements 122
Speeds 117, 131
Speed governor 135
Tablet 137
Tanks 126
Type 119
Type control 134
Wrenches 134

SMALL POWER PLANTS

Ammeters 163
Balanced voltage 162
Commercial kilowatt rating and speed of generator 154
Electric generators 153
Engines 147
Engines, compound corliss valve 150
Engines, compound single valve 149
Engines, simple corliss valve 147
Engines, simple single valve 147
Engines, specification 155
Estimate cost of plant 141
Estimate cost of labor 141
Equalizers 163
General arrangement of the apparatus 142
General practice 141
Generating units size 144
Generators 153
Generators, specification two wire 159
Generators, three wire 161
Interpole generators 153
Selecting an engine 150
Size and number generating units 144
Specification for engine 155
Specification for generator 159
Speed and ratings of generators 154
Switchboard connections 163
Temperature rise and overloads generators 155
Three wire generators 161
Ventilation of generators 154

MOTORS AND CONTROLLING APPARATUS

Alternating current motors 170
Armature control 671, 169
Control constant speed hand starting 173
Control, remote starting 174
Control, variable speed hand starting 174
Direct current motors 166
Field control 168, 170
Method of speed control D. C. motors 167
Phase wound induction motors 167
Remote control 168 169
Speed alternating current motors 170
Speed control 168
Speed direct current motors 166
Speed, phase wound 173

VACUUM CLEANING SYSTEMS

Base plate, foundations, etc 186
Centrifugal fan type 185
Cleaning tools 193
Drawings 189
Drive 186
Dust separators 189
Electric motors 186
Exhauster 184
Finish 186
General description 183
General practice 175
Hose 194

Page
Hose racks 194
Operating test 195
Piping 190
Piping, exhaust 191
Piping, fittings 191
Piping, sweeper outlets 191
Portable apparatus 196
Samples 195
Page
Size of plant 181
Speed of machines 185
Stationary 175
Sweeper outlets 191
Tests 195
Tools 180
Vacuum breaker 189

OPERATING DATA

Coal 198

APPENDIX

COMMERCIAL PRACTICE

(In regard to factory heating and forced hot water circulation systems.)

FACTORY HEATING

Air outlets 210
Amount of air for ventilation 231
Automatic temperatures regulators 230
Commercial practice factory heating 201
Cost, rough preliminary estimates. 233
Double duct system 230
Ducts and flues 209
Fan system 202
Heating coils 206
Heat losses 211
Humidifiers 209
Mechanical air removal system 213
Mechanical vacuum system 213
Piping, steam and return 207
Plenum chamber system 226
Prime movers 207
Properties of fans 234
Relative temperatures 232
Special requirements 222
Steam high and low pressure 207
Systems of exhaust ventilation 225

FORCED HOT WATER CIRCULATION

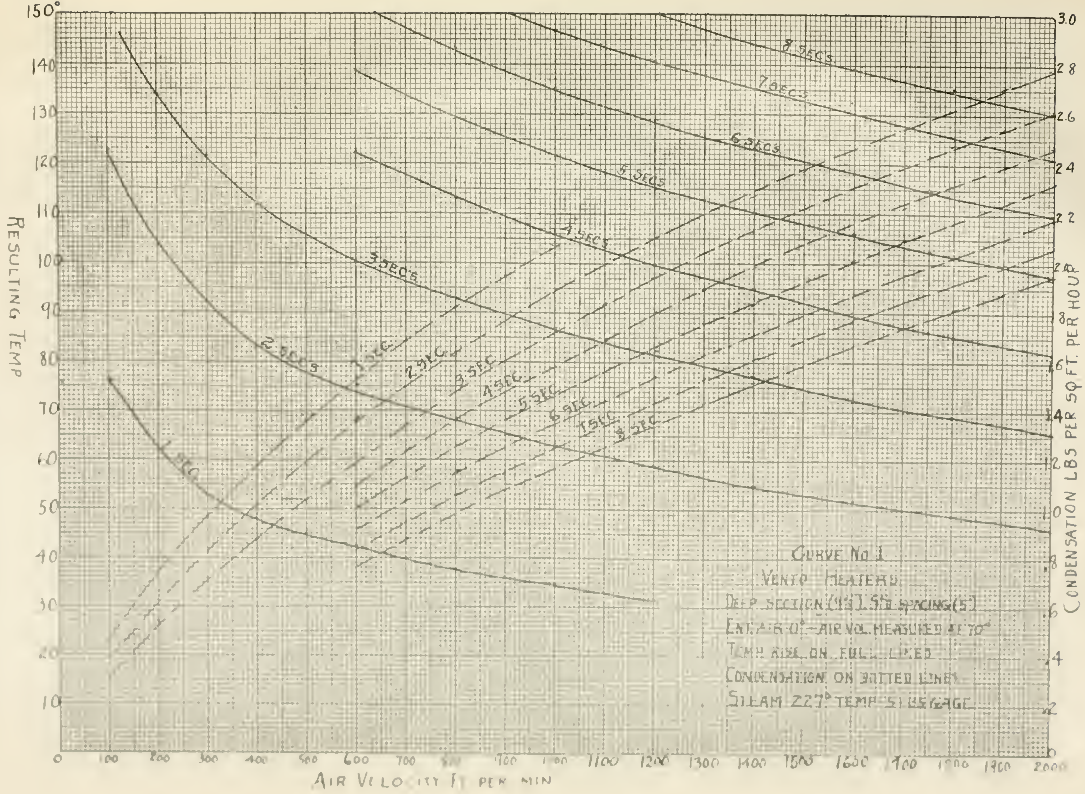
Advantage of hot water over steam. 245
Anchors 247
Boilers, hot water heating 255
Circulating pumps 255
Conduits 246
Connections, size of heater 254
Equipment 253
Exhaust and live steam heaters 254
Expansion 247
Expansion tanks 255
Heat available exhaust steam 254
Gauges and thermometers 255
Limitations of hot water systems ... 246
Live steam heaters 254
Mains, layout 249
Manholes 248
Pumps circulating 255
Quality of materials 246
Radiator connections 250
Radiators in individual buildings .. 248
Regulation 245
Valves 248
Water required to be circulated 250

GENERAL INSTRUCTIONS

	Page		Page
Conduit and wiring system	262	Plumbing and gas piping	263
Heating and ventilation	263	Size of drawings	263
Instructions to draftsman	256		

SUGGESTIONS TO SUPERINTENDENTS

Suggestions relative to mechanical equipment........ 265


Curve No 1
Vento Heaters
Deep section (9½) 5½ spacing (5")
Ent air 0° – air vol. measured at 70°
Temp rise on full lined
Condensation on dotted lines
Steam 227° temp 5 lbs gage
Resulting Temp
Air Velocity Ft per min
Condensation lbs per sq ft. per hour
1 sec
2 secs
3 secs
4 secs
5 secs
6 secs
7 secs
8 secs
1 sec
2 sec
3 sec
4 sec
5 sec
6 sec
7 sec
8 sec
150°
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
3.0
2.8
2.6
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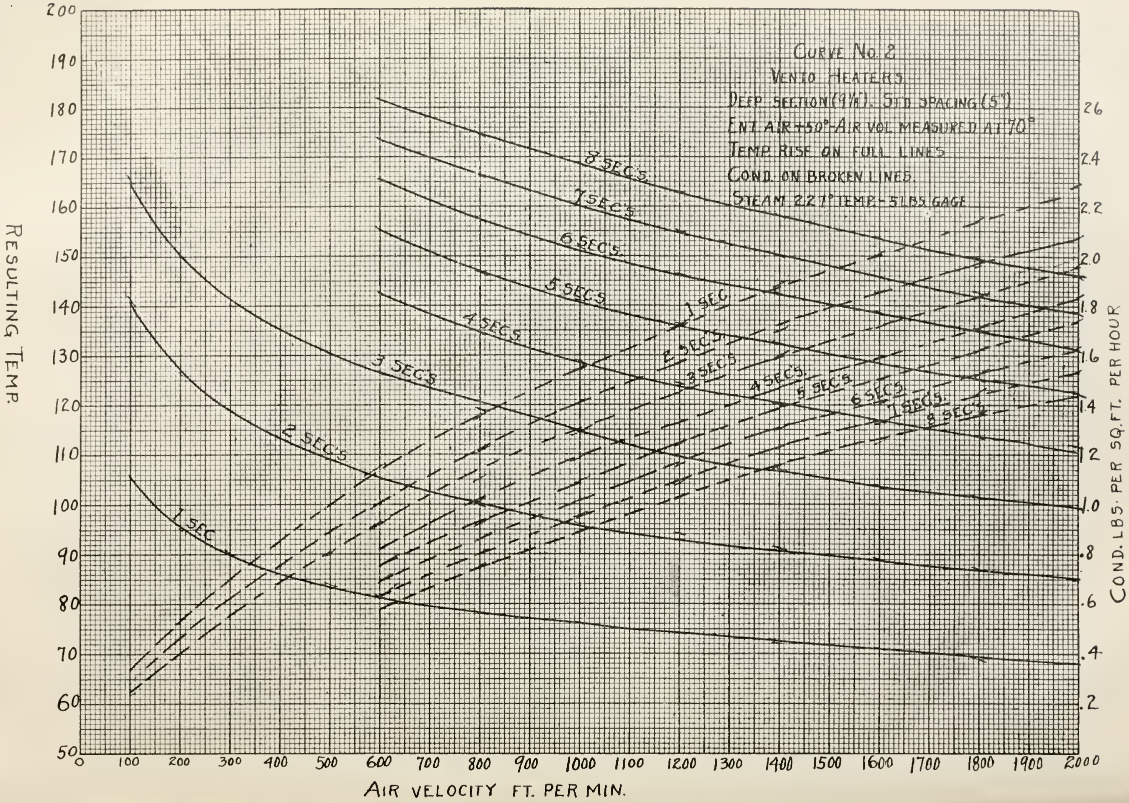
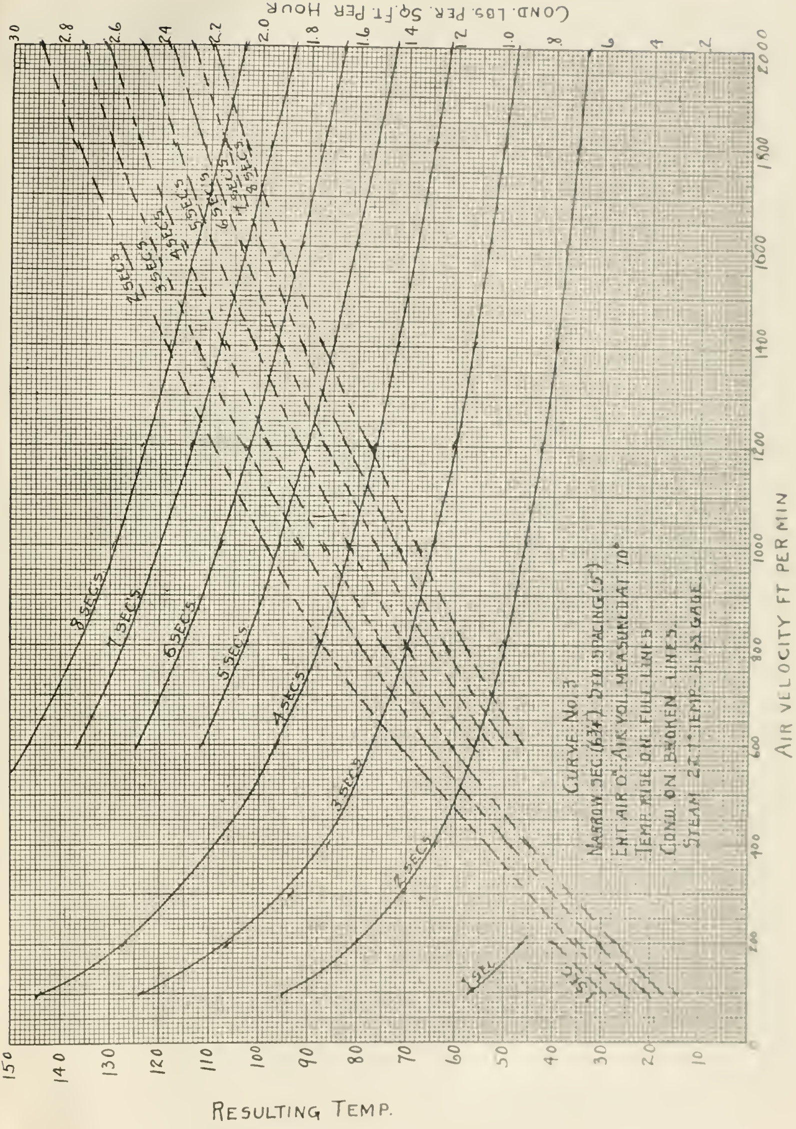
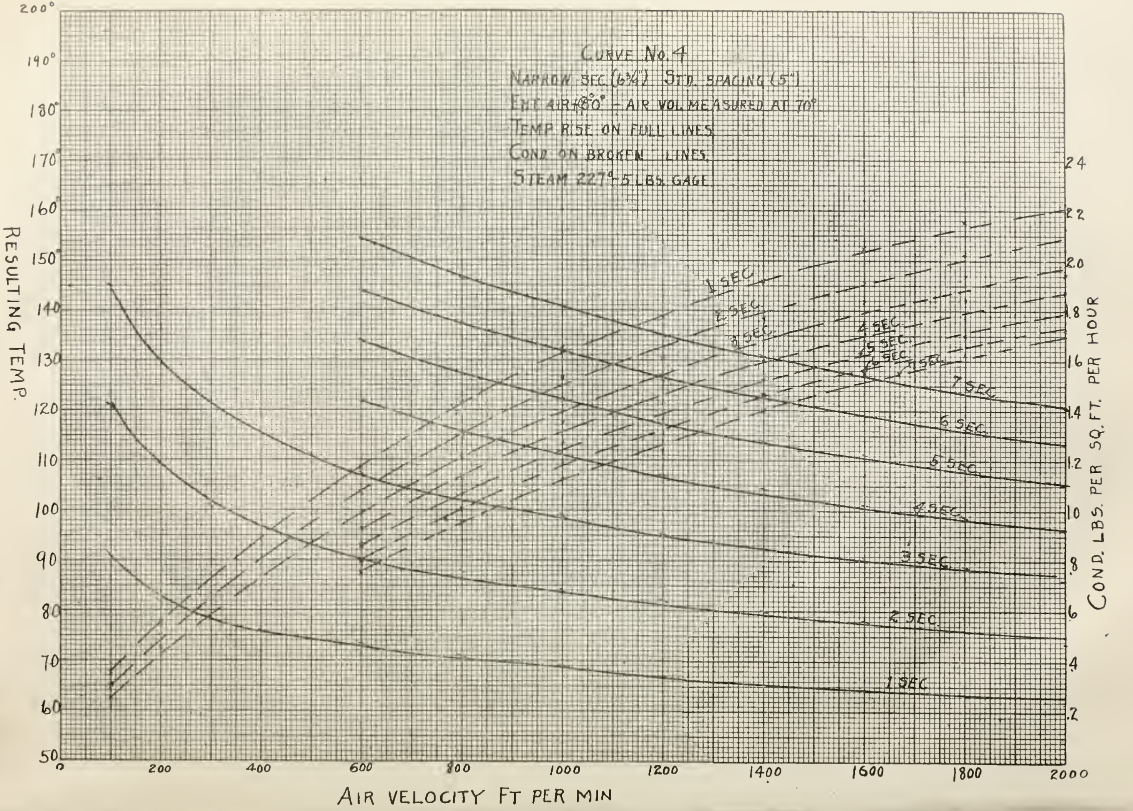
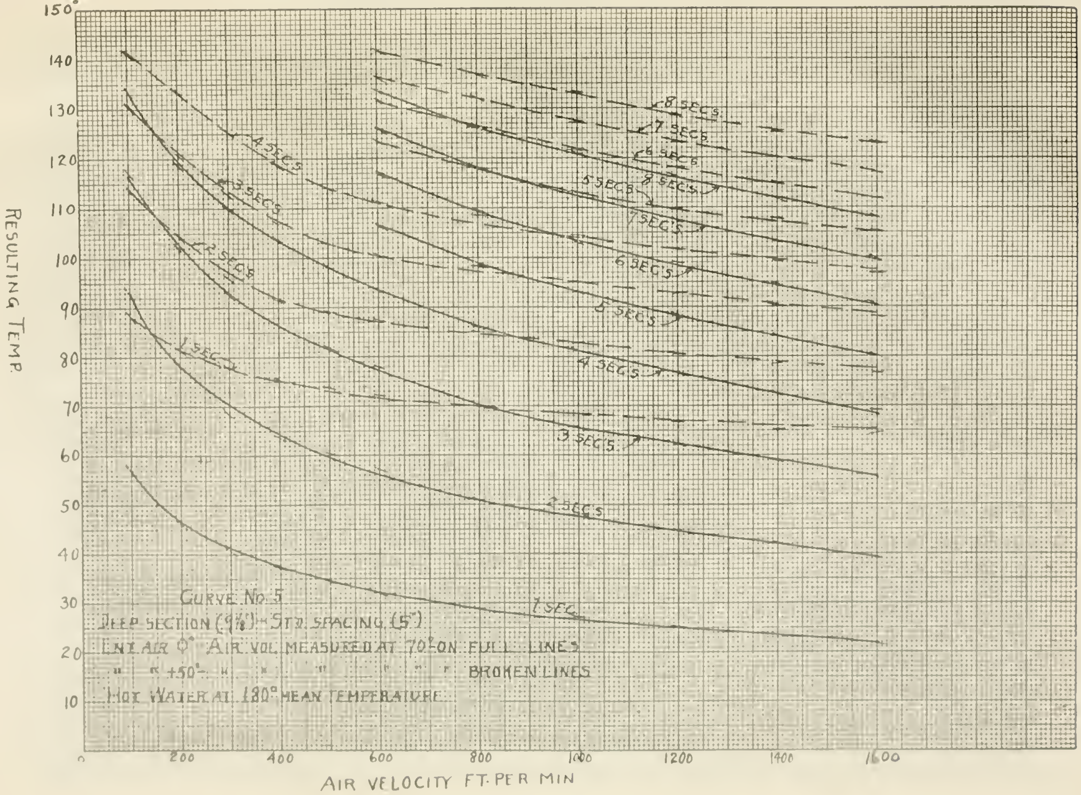
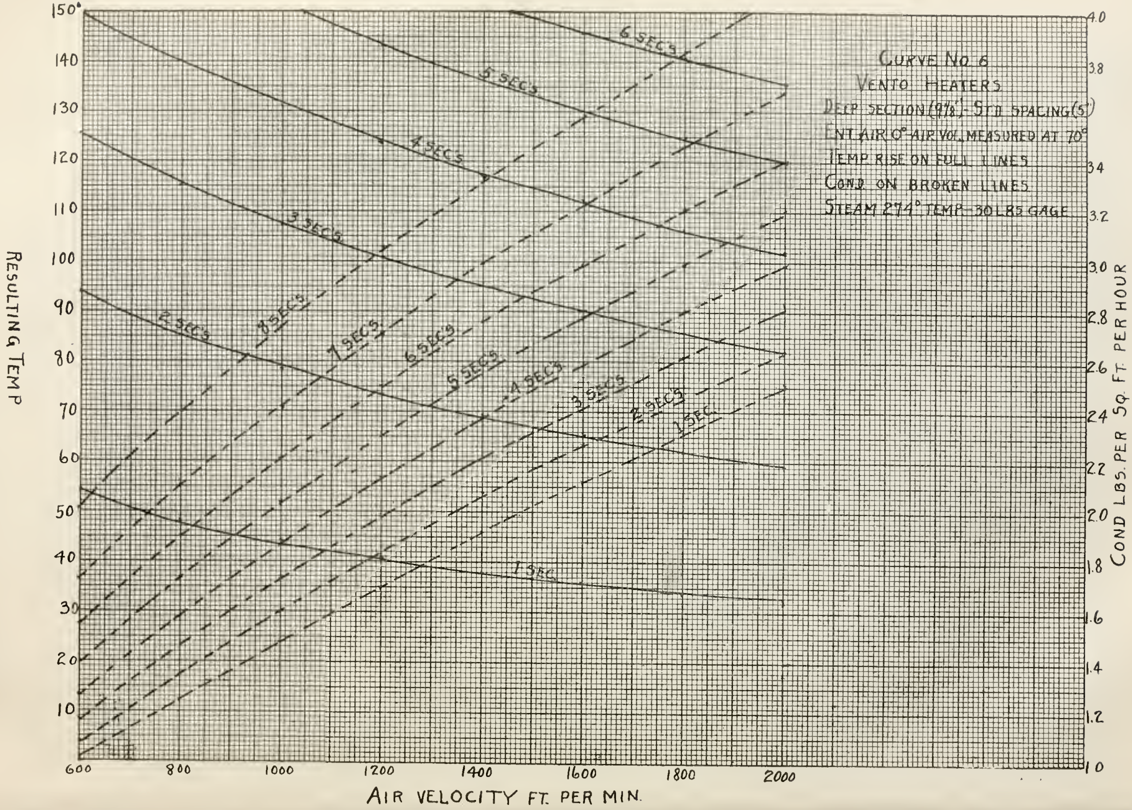

CURVE No. 2
VENTO HEATERS
DEEP SECTION (9⅛"). STD SPACING (5")
ENT. AIR +50°-AIR VOL. MEASURED AT 70°
TEMP. RISE ON FULL LINES
COND. ON BROKEN LINES
STEAM 227° TEMP. - 5 LBS GAGE
8 SECS.
7 SECS.
6 SECS.
5 SECS.
4 SECS.
3 SECS.
2 SECS.
1 SEC.
1 SEC.
2 SECS.
3 SECS.
4 SECS.
5 SECS.
6 SECS.
7 SECS.
8 SECS.
RESULTING TEMP.
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
AIR VELOCITY FT. PER MIN.
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
COND. LBS. PER SQ. FT. PER HOUR
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2



CURVE No 3
NARROW SEC (63+) DED SPACING (5")
ENT AIR 0° AIR VOL MEASURED AT 70°
TEMP RISE ON FULL LINES
COND ON BROKEN LINES
STEAM 227° TEMP 5 LBS GAGE
8 SECS
7 SECS
6 SECS
5 SECS
4 SECS
3 SECS
2 SECS
1 SEC
7 SECS
3 SECS
4 SECS
5 SECS
6 SECS
4 SECS
8 SECS
RESULTING TEMP.
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
AIR VELOCITY FT PER MIN
200
400
600
800
1000
1200
1400
1600
1800
2000
COND. LBS. PER. SQ.FT. PER HOUR
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2


CURVE No. 4
NARROW SEC (6¾") STD. SPACING (5")
ENT AIR 60° – AIR VOL MEASURED AT 70°
TEMP RISE ON FULL LINES
COND ON BROKEN LINES
STEAM 227° 5 LBS GAGE
1 SEC
2 SEC
3 SEC
4 SEC
5 SEC
6 SEC
7 SEC
7 SEC
6 SEC
5 SEC
4 SEC
3 SEC
2 SEC
1 SEC
200°
190°
180°
170°
160°
150°
140
130
120
110
100
90
80
70
60
50
RESULTING TEMP.
24
22
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
COND. LBS. PER SQ. FT. PER HOUR
0
200
400
600
800
1000
1200
1400
1600
1800
2000
AIR VELOCITY FT PER MIN


Curve No. 5
Deep section (9⅛") – Std. spacing (5")
Ent. air 0° Air vol. measured at 70° on full lines
" " +50° " " " " " " Broken lines
Hot water at 180° mean temperature
8 SEC'S
7 SEC'S
6 SEC'S
5.5 SEC'S
8 SEC'S
7 SEC'S
6 SEC'S
5 SEC'S
4 SEC'S
3 SEC'S
2 SEC'S
1 SEC
4.5 SEC'S
3.5 SEC'S
2.5 SEC'S
1.5 SEC
RESULTING TEMP.
150°
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
200
400
600
800
1000
1200
1400
1600
AIR VELOCITY FT. PER MIN


Curve No 6
Vento Heaters
Deep Section (9⅞") - Std spacing (5")
Ent Air 0° Air Vol Measured at 70°
Temp Rise on Full Lines
Cond on Broken Lines
Steam 274° Temp - 30 Lbs Gage
Resulting Temp
150°
140
130
120
110
100
90
80
70
60
50
40
30
20
10
Air Velocity Ft. Per Min.
600
800
1000
1200
1400
1600
1800
2000
Cond Lbs. Per Sq. Ft. Per Hour
4.0
3.8
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
6 SEC'S
5 SEC'S
4 SEC'S
3 SEC'S
2 SEC'S
1 SEC
8 SEC'S
7 SEC'S
6 SEC'S
5 SEC'S
4 SEC'S
3 SEC'S
2 SEC'S
1 SEC

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